PASSAMAQUODDY TIDAL POWER DEVELOPMENT

# FINAL REPORT

OCTOBER 15, 1936

## EXHIBIT A-4

UNITED STATES ENGINEER OFFICE
EASTPORT, MAINE

EXHIBIT NO. 4

(APPENDIX "A" - FINAL REPORT ON THE PASSAMAQUODDY PROJECT)

(a) Letter of President to Governor Brann
July 1, 1934.

(b) Passamaquoddy Bay Tidal Power Committee
Report.

The White House
Washington
July 1, 1934

My dear Governor:

"I am in full accord with your conviction that this is the proper time to take up in a serious way the possibility of developing the enomous latent electrical energy of the tide-waters of the Bay of Fundy, for the benefit of not only the citizens of the State of Maine but of the entire nation.

"With my summer home so near Eastport for so many years, I have been interested in what is known as the "Quoddy Project" for a long time, and it has been my hope that eventually the State of Maine would become not only a great industrial center of the nation but that its agricultural population would be among the first to enjoy the manifest advantages of cheap power on the farm as well.

"I also agree with you that the way to go about this in a practical manner is to be immediately appointed a commission to go over those definite projects which have been worked out by experienced engineers and select the best and most practical plans of those proposed. With this, however, there must go hand in hand a study of the ways in which this power may be put to work in the shortest possible time. There is for the time being a considerable amount of Government funds available for public works, some of which, of course, could be diverted to this purpose should it be found, first, that the creation of the power is practical and economical, and, second that it can be made available for various definite uses, and will not lie idle for many years to come, after it has been created.

"I think such a commission should have on it men whose reputations for judgment and ability are of the very highest order and the disinterestedness of whose motives cannot be questioned. Secondly, that a time limitation be put on the preparation of this report in order to take advantage of such public funds as are now at the disposal for purposes such as this. Of course, public money must first go to those projects which will employ the greatest number of people in the shortest time, and on works which, when created, will bring the most lasting and certain benefit to the people of this country. I have high hopes that the "Quoddy Project", after proper investigation, will prove to come under this category.

"I think it is also important that any definite plan be based upon securing of the title to the power site to the citizens and its use and development under the control of the State. No corporation or small groups of corporations should be given a monopoly in the use of this power or a title to what is the heritage of every citizen.

Governor Brann July 1, 1934

"I will await the report of such a commission in case you decide on taking such action with the greatest interest and can assure you that you will have a sympathetic ear in Washington for whatever recommendations may result from their studies.

Very truly yours,

FRANDLIN D. ROOSEVELT.

# R E P O R T

OF THE

PASSAMAQUODDY BAY TIDAL PROJECT

COMMISSION

***

WASHINGTON

JANUARY 17,1935

Legal - DPC/ICR

January 17, 1935.

The Honorable Harold L. Ickes,
Administrator of Public Works,
Washington, D. C.

Dear Sir:

The Commission appointed by you November 14, 1934 to examine and report upon the project for developing hydroelectric power by utilizing the tides of the Bay of Fundy near Eastport, Maine, submits herewith its report.

Very respectfully,

/s/ Dexter P. Cooper
Dexter P. Cooper

/s/ Henry T. Hunt
Henry T. Hunt

/s/ M. B. Pike
M. B. Pike

/s/ H. T. Cory
H. T. Cory

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# REPORT TO THE ADMINISTRATOR OF PUBLIC WORKS

The Commission appointed to examine and report on the project for the development of hydro electric energy by utilizing the tides of the Bay of Fundy near Eastport, Maine, herewith submits its report.

## RECOMMENDATION

The Commission recommends:

1. The inclusion of the immediate project in the comprehensive program of Public Works and the allotment of $30,000,000 to the War Department, Corps of Engineers, to finance its accomplishment, subject to the execution of a lease, satisfactory to the Administrator.

2. The creation by the State of Maine of an Authority, similar to the Power Authority of the State of New York, empowered to lease from the United States the project when completed; to construct and operate transmission lines and other necessary facilities; to sell electrical energy within and without the State of Maine; and to issue revenue bonds to finance the cost of such construction. The governing body of such Authority will consist of persons satisfactory to the President of the United States.

3. The lease from the United States to the Authority will provide for reasonable rental and will reserve the right to terminate the lease and to receive all or any part of the electrical energy generated if the President shall declare such course necessary to the national defense.

The project contemplated consists of:

A. The immediate project; consisting of a single basin, tidal power installation, utilizing Cobscook Bay; a power storage plant near Haycock Harbor; and a sixteen-mile electric transmission line connecting the two, all within the State of Maine, near Lubec and Eastport. (Details, p. xii.)

B. The ultimate project; consisting of a two basin tidal power installation by adding to the initial installation, additional works, embracing the Passamaquoddy Bay located partly in Maine and partly in New Brunswick, Canada. (Details, p. xii.)

FINDINGS

The Commission finds:

1. The immediate project is socially desirable. It will produce power at a cost of 3.4 mills (p. 65). Its ability to sell power at that price will control in the public interest power

rates throughout northern New England. It will thus promote in that region the President's policy of unifying the power system of the United States, extending the use of power and reducing its cost. Its accomplishment will alter the economic retrogression of the people of Maine into an economic advance. Its accomplishment will promote the national defense by making immediately available to the National Government a large volume of electrical energy at low cost. The employment provided will utilize locally twenty to twenty-five million man hours in useful work, absorb a major part of the unemployed now on relief in Maine at an annual expense of $7,500,000 per annum, of which the Federal Government is contributing in excess of $4,000,000.

2. It is economically feasible. As the project is a facility promotive of the national defense and general welfare a part of the cost may properly be charged to the nation. Furthermore it should be credited with the saving to the Government of its relief expenditures. While a market does not now exist sufficient to absorb and pay for the power generated at a price sufficient to amortize the cost of construction, neither did the Panama Canal in its early years amortize its cost. A market for Quoddy power will be in existence before a like market for Bonneville, Grand Coulee, Fort Peck or Caspar-Alcova. The Commission believes that such market will exist within five years. The basis for this opinion will be found p. 66, et seq., of this report, and pages 33 and 206 of the Maine State Planning Board's Report.

3. It is engineeringly sound. The only element novel in the United States is the utilization of power from tides. Such utilization, however, is in process abroad. The Severn Barrage Committee of the British Economic Council has investigated the utilization of the tides of the Severn Estuary and has recommended construction of the "Severn Tidal Power Project" with the approval of the British Economic Council. The work preliminary to construction is now under way. The parallelism of the Severn project with the Passamaquoddy Bay project is close. The latter will produce at lower unit cost than the Severn. Engineering technique, other than tidal, necessary for the accomplishment of this project is established. The War Department, Corps of Engineers, is competent and the appropriate agency to construct the work.

## The constitutional and Statutory bases of The Recommendations.

The Congress has power to provide for the common defense and general welfare of the United States and to dispose of property belonging to the United States. It has exercised this power by Title II of the Recovery Act which directs the President to prepare a comprehensive program of public works and to finance the cost of construction of any project included in the comprehensive program. He is further authorized to acquire and to lease any property in connection with the construction of any such project.

The primary purpose of the Recovery Act is the provision of nation-wide employment during the emergency declared, but emergency or not, the Congress has power to provide for the common defense and general welfare by such means as it deems appropriate. The establishment of a massive source of electrical energy reserved to the nation in case of need is ample justification for the appropriation and the lease proposed.

There can be no objection to the reservation by the State of Maine of concurrent jurisdiction in the area of the project to the extent that all civil and criminal processes issued under authority of the State may be served and executed thereon. However, that area should be the property of the nation.

Congress is also empowered to enter into compacts with the States and it would seem Congress may authorize the President to do so. Congress has entered into such compacts from the time of the admission of Ohio into the Union (Act of 1802) and lately by the enactment of the Boulder Canyon Project Act; by its consent to the compact of 1921 between New York and New Jersey creating the Port Authority of New York; and in numerous other instances. In Arizona v. California, 283 U.S. 423, the Boulder Canyon Project Act was sustained. The contract of lease proposed is a like compact and is authorized by Title II of the Recovery Act. The reservation that the members of the controlling board of the Authority shall always be satisfactory to the President of the United States is a valid condition of the proposed compact and is necessary in view of the national interest. The State of Maine has constitutional power to construct or acquire facilities for the generation of electrical energy and to operate them. By Chapter II of the Revised Statutes of Maine, 1930, it appears that the State has consented to the acquisition of land by the United States for any public purpose.

The justification of the national financing, as has been said, is the value of the project to the common defense and general welfare of the United States. Electrical energy at low cost available to the National Government and to the people is indispensable both for the common defense and for the general welfare. The appropriation of $165,000,000 to finance the purposes of the Boulder Canyon Project Act, appropriations to finance the purposes of the Tennessee Valley Authority Act, the national financing of Grand Coulee, Bonneville, Caspar-Alcova and Fort Peck under the authority of Title II of the Recovery Act are examples of the policy and practice of Congress and the Executive in the premises.

<u>The establishment of a self-liquidating market prior to construction may not fairly be demanded and is not feasible.</u>

The State's constitutional limitations with regard to the incurring indebtedness are such as to preclude it from contracting to reimburse the National Government. The State, however, may create an "Authority" with power to issue revenue bonds secured only by the income of the enterprise. Such bonds would not constitute an indebtedness of the State. The States of Washington

SUMMARY * Cont.

26. The plant will substantially increase the tourist business of Maine even now the largest source of income.

27. The Passamaquoddy Bay tidal power development is the most attractive undeveloped hydro-electric power opportunity of significant size in Maine.

28. Like Boulder Dam, Grand Coulee and Bonneville, Passamaquoddy is beyond the capacity of the State of its site and is national in aspect and value.

29. Its output will be absorbed before that of any of theother huge Federal hydro-electric projects except Boulder Dam, that project's major power customer is being Federally financed.

30. The cost of generation by tidal power will be less than that possible by coal or oil

31. It will fit into the nation-wide transmission line grid urged by the Mississippi Valley Committee.

32. Constant firm current can be sold at 2.5 mills per KWH to large users such as electric metallurgical and nitrate fixing industries. Power can be delivered to rural sections of Maine for less than 2 cents per KWH.

33. Such power exempt from seasonal or drought variations at such price will soon create its market.

34. Alternating current lending itself equally to a wide range of load factors, can be produced at correspondingly low figures.

35. Maine's economic and social status has been long retrogressing.

36. The Federal financing of irrigation works in the western states has regenerated their environments. A like effect on northern New England will be produced by this project.

37. Maine contributed through Federal taxation and its share of national lands to the regeneration of the arid west.

38. If Maine is to be aided the aid should come now.

39. The initial installation recommended for immediate construction would afford 20 to 25 million man hours of direct labor and 14 to 17 million of indirect labor.

40. All of the direct labor and about half the indirect labor, i.e. between 27 and 33 million man hours, would be performed in Maine, most of the remainder in the heavy industry centers of Pittsburgh and Chicago.

be the purchaser at the outset and waive interest for the period necessary. There is precedent for this. The Public Works Administration has waived interest to railroad borrowers for a period of one year. Reclamation contracts require no interest.

As the State of Maine is asked to contribute its submerged lands to the United States, their value to the nation may be considered also as a factor relieving the electrical consumers pro tanto. However, this Commission does not deem itself instructed to present all the terms of the proposed contract between the National Government and the "Authority". Those terms must be left for later determination. Among the matters to be later determined is the acquisition of the property of Dexter P. Cooper, Inc.

## Description of Project

In land locked bays and estuaries where the rise and fall of the tides are considerable, the amount of power latent in the tides is very great. In general this latent power may be ascertained when the volume of the bays is known and when the height of the tides is established.

At and near the mouth of the St. Croix River, a boundary stream between Maine and New Brunswick, there are two large bays, Passamaquoddy and Cobscook, which are arms of the Bay of Fundy and which are affected by the well known Fundy tides.

The initial or immediate project proposes the development of power from one of these bays, Cobscook, located wholly within Maine.

The final or ultimate project proposes the development of power from both Cobscook and Passamaquoddy Bay, located partly in Maine and partly in New Brunswick. Power will be obtained from these bays by artificial control of their levels. This will be effected by the construction of rock-fill dams and submerged control gates, and the construction of a power house of the usual low-head type enclosing penstocks, turbines direct connected to electric generators, all of a design identical to Cedars on the St. Lawrence or to Keokuk on the Mississippi.

The initial development is but a step or part of the general plan of the final development. Therefore a description of the operation of the final development will be given first.

The water supplying power to the turbines in the power house at the Muscle Shoals Dam comes from the flow of the Tennessee River. It enters the power house from the upper pool, or lake, formed by the dam. The water passes directly from this upper pool into the forebay of the power house, then into penstocks concealed in the power house and through the turbines and out of the power house into the tailrace, or lower pool, and then on down stream.

The operation of this tidal power plant will be similar in every respect to the Muscle Shoals plant. The upper pool, or lake, will be Passamaquoddy Bay, getting its supply of water from the ocean by means of the control gates instead of from creeks and springs as does the Tennessee River.

The power house will be located directly between the two bays and the lower pool or tailrace will be Cobscook Bay where the water discharged by the turbines will be collected and returned to the ocean through control gates instead of flowing on down stream. Technically speaking, the upper pool, or Passamaquoddy Bay, will be filled during a filling period of 2 hours on the peak of the flood tide, the upper pool reaching approximately the same level as the high water level of the flood tide. The lower pool, or Cobscook Bay, will be emptied on the bottom of the ebb tide, the emptying period requiring 3 hours. Between these two operations there are periods of time when neither pool is effected by the tide though the power plant is operating.

The immediate development, or initial step, embraces the works necessary for the "lower pool" and power house and in this case the ocean is the "upper pool" and flows directly into the power house. The operation of the "lower pool" is the same as heretofore described. The power output in this case is intermittent, for the ocean can only serve the power house for 7 hours. There is no upper pool to supply water until the succeeding tide arrives.

No two succeeding tides rise or fall to the same levels. These natural conditions effect pool levels causing a fluctuation in the amount of the power output, whether one or two pools are used. Furthermore, tides come and go and if their power is not used when generated it will be wasted. There is still another important element to be considered. The demand for power by the public varies throughout the day, the week, the month and the seasons. A warehouse is required to effectively regulate these variables.

Technically this is known as a "Power Storage Plant", where unused electric energy generated at the main tidal power house may be warehoused subject to the consumers demands. In general, these power storage plants, now in use in this country and abroad, consist of a reservoir located near an ample supply of water. Usually the reservoir is at a much higher elevation than the supply of water. Excess or surplus electrical energy is used for pumping water into the reservoir, thus converting electrical energy into potential hydraulic energy. The inversion from potential hydraulic energy to electrical energy takes place in the ordinary way, i.e. by means of turbines and generators.

The initial or immediate Passamaquoddy Project includes a power storage plant sufficient in reservoir capacity to serve the final major project (two bays). It is located on the ocean at Haycock Harbour, 16 miles, by transmission line, from the main tidal power house. Nearby is a natural reservoir 135 feet above sea-level. Seawater will be used instead of fresh water. This plant will operate as an automatic station without interruption to service.

This power storage plant has a great advantage in that it will serve not only as a warehouse for excess power, ready at all times to receive power and also to deliver power at almost any load factor, but also as a standby plant to the main generating station.

## Reference examined

1. "Severn Barrage Committee Report". Made to the Economic Advisory Council of Great Britain and printed by his Majesty's Stationery Office. London. 1933. 28 pp.

2. "Severn Barrage Committee Appendix". Report of Export co-ordinating sub-committee". Made to the Economic Advisory Council of Great Britain, and printed by his Majesty's Stationery Office. London. 1933. Plans diagrams and figures appended to the Report in Separate Wallet.

3. "Construction and Operation of a tidal model of the Severn Estuary". Two reports, by Professor A. H. Gibson, Dr. Sc. made to the Economic Advisory Council of Great Britain by the Severn Barrage Committee, and printed by his Majesty's Stationery office. London. 1933. vii + 314 pp. 113 figures and 3 plates in a separate Wallet. Library of Congress Book Number "TC 464 84 A 5 1933a".

4. "Proposed tidal hydro-electric power development of the Petitcodiac and Wemramook Rivers". W. R. Turnbull, Jour. Eng. Inst. of Canada, Oct. 1919. Reprinted in the annual report of the Smithsonian Institute for 1923. Govt. Print. Washington. 1925. pp. 523 - 546. Library of Congress Book Number "Q 11 S6S year 1923".

5. "Tidal Power". Maj. A. M. A. Struben. Pitman & Sons, Ltd. London. 1921. xii + 115 pp. Library of Congress Book Number "TC 147 S8".

6. Studies in Tidal Power." Norman Envoy. Constable & Co. Ltd. London. 1923 xii + 268 pp. Library of Congress Book Number "TC 147 D3".

7. "Report by the International Passamaquoddy Fisheries Commission". Appointed under an act of Congress approved June 2, 1930 to investigate the probable effect of the damming of Passamaquoddy and Cobscook Bays on the fisheries of that region. House Document No. 300 73rd Congress, 2nd Session April 9, 1934. Govt. Print. Washington. Library of Congress Book Number "SH 11 A6 1934c".

8. "Etude sur l'utilisation des marees pour le production de la force motrice." E. Maynard. Revue Generale de l'Electricitie. Paris. 1919. i + 123 pp. Library of Congress Book Number "TC 147 M3".

9. "Les marees et leur utilization industrielle". E. Fichot. Gauthier-Villars et Cie. Paris. 1923. vi + 255 pp. Library of Congress Book Number "QB 415 F5".

10. "Etude sur l'Utilization de l'energie des marees en France". Georges Mareau. Librairie Delagrave. Paris. 1931. i + 102 pp. Library of Congress Book Number "TC 147 M65".

11. "L'application du systeme de distribution Thury, par courant continu a intensite constant, au project d'usine maremotrice de la Frenaye" (Cotes-du-Nord). Louis Schwob. Le Genie Civil. Paris. Vol. 90 pp. 500-504. May 21, 1927. Library of Congress Book Number "TA 2 G3".

12. "L'Electrification industrielle et rurale de la France". P. Pacoret. La Vie Technique et Industrielle. Paris. 1931. 465 pp.

13. "Utilization de las marees de la costa Patagonica". Comision Nacional Honararia de la Academia de Ciencias Exactes, Fisicas Y Naturales de Buenos Aires. Tomas Palumbo. Buenos Aires. 1928. 381 pp. Library of Congress Book Number "TC 147 A7".

14. "Ditto Part II. Posible aplicacion de las fuerzas hidraulices. 167 pp. Library of Congress Book Number "TC 147 A7 1928a".

15. "Die techinschen und wirschaftlichen grundlagen fuer die Gewinnn von Gezeitenergie". Dr. Walter Stuerzenocker. VDI - Verlag. G.mb.H. Berlin. 1929. iv + 52 pp. Library of Congress Book Number "TC 147 S85".

## SUMMARY

1. The only novel element of the project is the utilization of the tides. This element has been exhaustively examined by the Severn Barrage Committee of the British Economic Council which concluded that power could be developed from the tides of the Severn Estuary cheaper than by the most modern coal burning installation although large scale coal mining is adjacent to the Severn Estuary. The Committee's recommendation for immediate construction of the Severn Tidal Power Project has been approved by the British Economic Council. The work preparatory to construction is under way.

2. While the Severn tides are higher than those in Passamaquoddy Bay, the Severn topography is less favorable. The ultimate Passamaquoddy installation will produce more power at less cost.

3. The parallelism of the Severn Estuary project with the one at Passamaquoddy Bay is close.

4. The essentials for tidal power projects are high tides and topography permitting cheap construction of adequate basins.

5. That the peculiar characteristics of tidal power projects are (1) large and gradual variations of total daily output with the maximums and the minimums a month (a lunar cycle) apart, and (2) absolute dependability.

6. Ironing out these variations of power output necessitates power storage consisting of a high lying reservoir into which water is pumped during power peaks at the main tidal plant, and let out through turbo-generator units to fill in power valleys of the main plant.

7. The power storage capacity required for such regularization is greater than that required for the twice daily tidal ranges.

8. The use of two or more tidal basins reduces unit energy costs.

9. Topography at the Severn permits only one tidal basin.

10. The ultimate Passamaquoddy installation will provide two tidal basins.

11. One such tidal basin will be sufficient at the outset, is engineeringly justified and is recommended.

SUMMARY - Cont.

12. Construction of the storage reservoir to nearly its ultimate capacity is recommended now.

13. The topography about Passamaquoddy Bay is peculiarly favorable to cheap power storage.

14. The proposed tidal power installations will affect the shape and total range of tidal curves.

15. The mathematical computation of such affects is theoretically possible but the accuracy of the result is doubtful.

16. For this and other reasons the Severn Barrage Committee had constructed a 47 foot model of the Severn Estuary, on which such effects were experimentally determined.

17. The experiments demonstrate that the reduction in tidal range which will result from the initial Passamaquoddy Bay installation will not exceed 2 percent.

18. The effect upon navigation will be nil other than on Cobscook Bay, relatively small locks will provide for that Bay's requirements.

19. The effect of the initial installation on fisheries will be negligible.

20. Damage to other local interests will be insignificant.

21. Siltation in Cobscook Bay will be increased but the increase negligible.

22. The dams creating the tidal basins will permit railway service, now ending at Eastport, to be continued to Lubec and will reduce the highway distance from Eastport to Lubec from 40 to 2 miles.

23. Hence a portion of the installation cost may be charged to facilitation of transport.

24. No single technical feature of the project is new or other than standardized.

25. Nevertheless the novel incorporation of common elements into a whole, will strike the imagination and improve the morale of the American people. Quoddy will be among the nation's wonders.

SUMMARY * Cont.

26. The plant will substantially increase the tourist business of Maine even now the largest source of income.

27. The Passamaquoddy Bay tidal power development is the most attractive undeveloped hydro-electric power opportunity of significant size in Maine.

28. Like Boulder Dam, Grand Coulee and Bonneville, Passamaquoddy is beyond the capacity of the State of its site and is national in aspect and value.

29. Its output will be absorbed before that of any of theother huge Federal hydro-electric projects except Boulder Dam, that project's major power customer is being Federally financed.

30. The cost of generation by tidal power will be less than that possible by coal or oil

31. It will fit into the nation-wide transmission line grid urged by the Mississippi Valley Committee.

32. Constant firm current can be sold at 2.5 mills per KWH to large users such as electric metallurgical and nitrate fixing industries. Power can be delivered to rural sections of Maine for less than 2 cents per KWH.

33. Such power exempt from seasonal or drought variations at such price will soon create its market.

34. Alternating current lending itself equally to a wide range of load factors, can be produced at correspondingly low figures.

35. Maine's economic and social status has been long retrogressing.

36. The Federal financing of irrigation works in the western states has regenerated their environments. A like effect on northern New England will be produced by this project.

37. Maine contributed through Federal taxation and its share of national lands to the regeneration of the arid west.

38. If Maine is to be aided the aid should come now.

39. The initial installation recommended for immediate construction would afford 20 to 25 million man hours of direct labor and 14 to 17 million of indirect labor.

40. All of the direct labor and about half the indirect labor, i.e. between 27 and 33 million man hours, would be performed in Maine, most of the remainder in the heavy industry centers of Pittsburgh and Chicago.

SUMMARY - Cont.

41. The many and diverse benefits which are possible by carrying out the recommended project will not be attained unless the direction thereof be efficient, consistent, aggressive and of steadfast purpose. The nation's interest is such as to warrant Executive satisfaction with the directing personnel.

42. There is already a large capital investment ready at hand in roads, homesteads, farms, docks, stores, shops, etc. capable of serving a large increment of population.

43. Passamaquoddy Bay forms a deep water international harbor of prime importance capable of very considerable service especially as the receiving point of heavy or bulky raw materials or the distribution of finished products.

# ENGINEERING AND ECONOMIC ANALYSIS.

## Appointment

On November 14, 1934, the undersigned were appointed a Commission to examine and report upon all significant phases of the Passamaquoddy Bay Tidal Power Project.

As soon as practicable the Commission set to work, the first meeting of all the members being at Welchpool, New Brunswick, November 20th, 1934. Numerous Commission meetings and conferences with representatives of interests which would be affected by building of the Passamaquoddy Project have been held; the documents in connection with all previous reports and investigations of the Project have been exhaustively examined; the characteristics of tidal power development in general studied; and plans and cost estimates of an initial development at Passamaquoddy Bay agreed upon.

## History of Investigations

In 1919 Dexter P. Cooper began seriously developing plans for the utilization of tidal power in Passamaquoddy Bay at the Eastern corner of Maine. He enlisted the assistance of several elements financially interested in hydro-electrical power work and which collectively supplied a large amount of money, about $400,000, and investigated the project from practically every angle. All the data so collected was placed at this Commission's disposal.

These examinations covered a period from 1925 to 1934, with the exception of an interim from 1931 to 1933 when the work was interrupted from various causes.

In 1925 a special charter was granted Dexter P. Cooper, Incorporated, by the State of Maine, through legislative action requiring a referendum by the Maine electorate who, in September 1925, approved by a vote of seven to one. This charter contains certain unusual and important provisions. A copy of it is attached hereto as Appendix "A".

In the Spring of 1926 a charter was granted an allied Canadian Dexter P. Cooper Company by the Dominion of Canada. This Canadian charter required beginning actual construction work within three years. This was found impractical and renewals have been secured so that the charter is still in effect.

Meanwhile plans had been evolved for an ultimate international installation and for a much smaller or initial project embracing only territory within the United States.

Application was made to the Federal Power Commission of the United States for a preliminary permit for the international development and this was granted in May, 1926. Application was likewise made to the Department of Marine and Fisheries and the Department of Public Works of the Dominion of Canada, and these are pending.

In 1929, the investigation had sufficiently progressed to render desirable an international expression of opinion regarding the effect of the international project upon the fishing industry of the region. In 1930 the International Passamaquoddy Fisheries Commission was created, the final action of the United States Congress being June 9, 1930. A total of $90,000 was appropriated, one-half by each country. The members of this Commission were W. A. Found, Deputy Minister of Fisheries, and Dr. A. G. Huntsman, Senior Director of the Dominion Biological Board, representing Canada, and Henry O'Malley, Commissioner of Fisheries, and O. E. Sette, Special Investigator of the United States Bureau of Fisheries, representing the United States.

In April, 1934, such Commission reported to both Governments and the copy addressed to the United States Secretary of State was published as House Document No. 300, 73rd Congress, 2nd Session, copy of which is attached as Appendix "B".

The Passamaquoddy Tidal Power Project was also reported upon in 1926 and 1927, by Messrs. Murray and Flood, Consulting Engineers of New York City, retained by the financial interests who financed the primary engineering investigations.

When the United States Federal Power Commission granted the preliminary permit heretofore mentioned, it placed jurisdiction in the matter under the War Department and it was referred to the Boston Office of the United States Army Engineer Corps. Monthly reports were made from 1926 to 1930, as to work accomplished, money expended, etc.

In the meantime, application was made to the Federal Power Commission for a license to build a modified and smaller project, entirely within the United States. No definite action has yet been taken in reference to granting this license, due in large part to circumstances set forth in the following paragraph.

In the Fall of 1933, application was made to the Public Works Administration of the United States for a loan to construct this smaller American project. This produced an anomalous state of affairs in that the Public Works Administration required as a condition precedent, possession of a Federal Power Commission license, while such license requires a showing of ability to immediately construct if granted.

The Public Works Administration made an examination of the application, Docket No. 1641, and denied it, finding that the project did not comply with the Public Works Administration's standards for self-liquidating loans. This examination including a hearing held by such Administration's Technical Board of Review and a report by the Federal Power Commission. The report of the Technical Board of Review dated March 30, 1934, is attached as Appendix "C", and the report from the Federal Power Commission dated January 3, 1934, is attached as Appendix "D".

In July, 1934, Governor Brann of Maine appointed a special commission of five headed by Dr. Kenneth Sills, President of Bowdoin College which made a report, January 4, 1935, copy of which is attached as Appendix "E".

On November 14, 1934, the Administrator of Public Works, Harold L. Ickes, appointed the present Commission.

All such reports and data heretofore mentioned have been available to and considered by this Commission.

In addition careful study has been given to the exhaustive reports of the so-called Severn Barrage Committee to the Economic Advisory Council of Great Britain upon the proposal of a tidal power development in the Severn Estuary on the west coast of Great Britain.

This Severn Barrage Committee consisted of 10 members and was appointed October 12, 1925 to "Inquire into and report upon the practicability of the Severn Barrage". The report of this Committee constitutes by far the most exhaustive review and report upon any tidal power development which has ever been made. The Committee not only had ample funds, £50,483, or at the standard rate of exchange, $245,852.21, at its disposal, but spent seven and one-half years from the time of its creation to its final report. It was composed of very capable members as follows:

Lieut. Colonel J. T. C. Moore-Brabazon, M. C., M. P., Chairman.

Mr. G. S. Albright, C. B. E.

Mr. H. F. Carlill, Assistant Secretary, General Department Board of Trade.

Vice-Admiral Sir H. P. Douglas, K. C. B., C. M. G. late Hydrographer of the Navy.

Professor A. H. Gibson, D. Sc., M. Inst. C. E., M. I. Mech. E., Professor of Engineering, Victoria University, Manchester.

Mr. B. W. Gilbert, Assistant Secretary, Treasury.

Sir Syril W. Hurcomb, K. B. E., C. B., Permanent Secretary Ministry of Transport.

Sir Basil Mott, Bt., C. B., F. R. S., M. Inst. C. E., Senior Partner, Messrs. Mott, Hay and Anderson, Consulting Engineers of London.

Sir Frank E. Smith, K. C. B., C. B. E., D. S., Sec. R. S. Secretary, Department of Scientific and Industrial Research.

Sir John Snell, G. B. E., M. Inst. C. E., M. I. E. E., Chairman Electricity Commission.

Mr. Francis Hemming, C. B. E., Joint Secretary, Economic Advisory Council, and

Mr. T. Shirley Hawkins, O. B. E., M. Inst. C. E., Ministry of Transport, Joint Secretaries to the Committee.

It is impracticable to attach copies of the Severn Barrage Committee reports consisting of three volumes and two portfolios, but copies are in the Library of Congress.

Relatively soon after its creation, this Committee had constructed in the laboratory of Victoria University in Manchester, England, and under the direction of Professor A. H. Gibson, of that institution, a model of the Severn Estuary, about 47 feet long.

Very ingenious devices and arrangements were provided for duplicating the exact tidal conditions with and without the proposed power development for periods equivalent to more than 100 years time. Through the operation of this model, determination was made as to the effect of the proposed installation on all features of interest including:

(a) Tidal levels.

(b) Amount of tidal water passing up the Severn Estuary.

(c) Navigation.

(d) Silt deposition in the tidal basin.

(e) Land Drainage.

(f) Sewerage contamination.

(g) Floods.

(h) Configuration of the bed of the Estuary.

(i) The adjacent Forest of Dean coal mines.

(j) The waterway connecting Birmingham and the Severn Estuary.

(k) The highway connection between South Wales and the Southwest of England.

(l) The railway connection between South Wales and the Southwest of England.

(m) The Severn and Wye Fisheries.

The members of this Commission wish to express particular appreciation of the valuable technical information indirectly and directly applicable to the Passamaquoddy Bay Tidal Power Project contained in this Severn Barrage Committee's report.

Essential Conditions for Feasible Tidal Power Project.

There are three requisites essential to economically justifiable tidal power projects.

The first is a large tidal range, because the potential power varies as the square of such range. By tidal range is meant the difference in elevation between the high and low water points of any tidal cycle.

In the open sea this is only about two feet, but increases to varying degrees because of something very similar to a pendulum effect. Since these effects depend upon the configuration of the shore, there are many places in the world where the ocean's normal tidal range is magnified up to five times, and a relatively few where such magnification reaches anything like ten times.

The only points where the mean range is 18 feet or more, are:

1. Cook Inlet, Alaska.
2. Straits of Magellan.
3. North West Coast of Australia.
4. Gulf of Cambay, India.
5. 6. Two places in China.
7. 8. Two places near Hudson Bay.
9. Head of the Gulf of California.
10. North Coast of France.
11. West Coast of England.
12. Bay of Fundy.

The second requisite is favorable topography for the necessary engineering works. Obviously, water of the ocean must be let into a pool or pools cut off from the main water by a barrier, and power developed either during inflow, outflow, or both. The power output obtainable from a tidal power development varies directly with the volume of water entering and leaving this pool, which in effect, amounts to varying with the area of the pool.

These two requisites collectively merely state in another form that the power developed by falling water varies directly as the amount of water falling and as the distance through which the water falls.

The third requisite is that such tidal power development should be within reasonable transmission distance from where the power may be used, i.e., not widely distant from power using population.

When applying these three conditions to the foregoing list of places where the maximum mean tidal range is 18 feet or over, it is seen that there are three locations which are definitely outstanding as compared to all the others, i.e., the west coast of England, the north coast of France, and the Bay of Fundy.

In consequence, the examination of all possible phases of tidal power developments have been limited to, but have been exhaustively carried out for, these three locations. In addition, the Government of the Argentine Republic has done a good deal of preliminary work in examining possibilities of tidal power developments in the Gulf of San Jose.

It is also essential, from a scientific standpoint, to ascertain the ultimate theoretical possible power output in any tidal project. In the case of Passamaquoddy Bay the ultimate possible theoretical amount of power possible to develop would be 11,000,000,000 KWH per annum. It is proposed to develop 333,000,000 KWH in the initial development and 3,100,000,000 KWH in the ultimate international development.

Peculiar Characteristics of Tidal Power Development

Before proceeding with a detailed consideration of the three tidal power projects which have been exhaustively investigated in England, France and the Bay of Fundy, it is desirable to set forth some peculiar characteristics of tidal power developments as contrasted to ordinary hydro-electric installations on streams or at the outlets of lakes and reservoirs.

Tidal Variations

The existence of tides is due to the attractive force exerted on the earth by the sun, the moon and other heavenly bodies. These forces vary directly as the masses and inversely as the square of the distances. Even the stars have theoretically, at least, influence, even though often infinitesimally small. Inasmuch as in no two instants of time can the earth ever be in exactly the same relative position as regards all heavenly bodies, it is impossible that any tidal cycle can ever be exactly reproduced.

As a practical matter, however, there are four effects, in comparison to which all the others are relatively insignificant.

The first in importance is due to the attraction of the moon, for while the mass of the moon is much less than that of the sun, so also is its distance, with the result that the moon influence is 2.73 times that of the sun. To this influence is due the high and low water twice daily, or more exactly, every 12 hours and 25 minutes on the average. Speaking of a tidal cycle, this is the one which is generally meant.

The second cycle in importance, is the one due to the sun's attraction. When the moon's and the sun's attractions are combined, the effect is a maximum, and then occurs what is known as the spring or maximum tides. When these influences oppose each other, the range is a minimum, and the neap or minimum tides result. Obviously there are two periods of spring tides and two periods of neap tides every month.

The third cycle, and a very important one in the Bay of Fundy, is that due to the variation of distance from the moon to the earth, because the moon travels in an eliptical path, with the earth at one of the foci. This variation of distance alters the attraction, and when the moon is closest to the earth or at its perigee, the effect as indicated by the tidal variation is greatest, and when at its apogee or farthest point, is least. This cycle has a period of approximately a month.

The fourth effect is the result of the angle the moon's orbit makes with the axis of the earth, or in other words, the moon's declination. This cycle indicates itself in the tides as a difference in elevation between succeeding high waters and succeeding low waters. At Passamaquoddy Bay this will sometimes mount to two feet.

There are several minor moon influences which cause variations of longer periods such as nine and nineteen years. The variations and the influences of other heavenly bodies have already been mentioned and are vastly less important.

The tidal predicting machine at Washington is capable of handling 37 harmonic variations, although practically speaking, 12 or 13 will give quite reliable predictions as to the time, the shape of the tidal curve (elevations plotted against time) and the total tidal variation.

To secure data for any particular locality it is necessary to determine by actual observations the total variation and the lag in time of high and low tides as compared to some other near by point at which tidal phenomena have been determined by actual observations. For example, it is found that the range of the tide at various points on the Bay of Fundy increases rapidly from the mouth of the Bay to a maximum at the head thereof near Hopewell, New Brunswick. Such increase in tidal range towards the heads of estuaries is common to practically all estuaries of this type. It is best understood as a pendulum effect. This tidal sweep goes in every direction which it can, and consequently swings sideways through the Passamaquoddy Bay up the St. Croix River, as well as following the Bay of Fundy itself to its northeast end.

The increase in range due to the momentum or pendulum effect in the open Bay has a definite percentage relationship for every point of reference.

At the main dam site for the tidal power plant to be built in the Severn Estuary on the western coast of England, the average yearly range is 32.6 feet; at the proposed tidal power development at Aber-Vrac'h near the northeast corner of France, the maximum spring tide is 27 feet and the minimum neap tide is 8.2 feet; and at Passamaquoddy Bay the average yearly range is 18.55 feet.

Stated in terms of theoretical developable power for a unit of volume, or as heretofore explained, a unit of area, in the tidal basins, that at the Severn is 310% of that at Passamaquoddy Bay. The apparent advantage hereis sharply in favor of the Severn development, but as will be seen later, this is more than offset by the topographical conditions at Passamaquoddy Bay permitting more advantageous and economical creation of essential tidal basins.

If all tidal ranges through the year were equal, tidal power plants would long since have been more or less common.

However, the maximum perigee spring tide at Passamaquoddy Bay for example is over 26 feet, and the minimum apogee neap tide only about 12 feet. That means that, since the potential power varies with the square of the range, that the minimum amount for any one tide is 21% of the maximum.

These extreme variations, however, are misleading in that they are the result of maximum or minimum astronomical relations combined with extreme local conditions such as high winds and high or low barometric pressures. The significent variation is the 90% point or that range which will not be exceeded during 90% of the time. At Passamaquoddy Bay for 90% of the time, the range will be less than 22.5 feet as a maximum and for 90% of the time more than 15 feet as a minimum.

Even within these range limits the potential power during the higher range will be 225% of that during the lower range. Mathematically speaking, a series of tidal cycles is a series of very nearly exact sine curves, each with a time spread of 12 hours and 25 minutes, and with varying amplitudes. True sine curves are departed from more and more as the head of an estuary is approached with the consequent tidal exaggeration due to the friction or dragging of the wave on the bottom.

Because of the large variation in thepotential power between spring tides and neap tides, it follows that regularization or equalizing the power developed throughout a single tidal cycle, is far from sufficient to obtain constant power output. A diagram for a year showing daily output would consist of approximately 12 monthly cycles, the bottom points of which would be only 44% of the high point, and 65% of the mean.

## Power Storage.

To iron out these severe variations of output, an essential factor of any practicable large scale tidal power development is some form of power storage. That is to say, much of the output when it exceeds the average must be stored in some way for release to supplement the small amount of power developed at other times.

Theoretically, there are several methods of securing this power storage, such as warehousing it as electrical energy in electric storage batteries or in the form of heat in large thermal storage units. Practically speaking, neither of these methods are feasible. The only procedure to be considered is now termed hydraulic power storage. This consists of using much of the high power peaks for pumping water into a distinctly higher reservoir and letting this pumped water run out through turbines for the generation of supplementary power during periods of low tidal power production. The amount of water to be pumped varies inversely with the distance the water is elevated.

All of the three tidal power developments herebefore mentioned,

i. e., in the Severn Estuary in England, at Aber-Brac'h on the northwestern coast of France, and that at Passamaquoddy Bay, will utilize hydraulic power storage in identically the same way.

In the Severn development, water will be pumped from a little above sea level into a reservoir, the water surface of which will vary from 300 to 500 feet above sea level. At Aber-Vrac'h, the maximum and minimum elevation of water storage elevation will be 160 and 110 feet, and at Passamaquoddy Bay, 135 feet and 100 feet respectively. In all cases the reserve or power storage will have adequate capacity to completely level off the daily, monthly and yearly power variations, and permit supplying energy to practically any form of power use curves and load factors which may be desirable.

This inevitable power storage appendage of tidal power installations has both advantages and disadvantages. The chief disadvantage is that it involves a loss of energy through double handling of water. The advantage is that while with hydroelectric power installation in running streams the unused power at any moment is lost forever, with such hydraulic storage it is stored for a possible rather remote future use, and in any event, exactly when and as desired, according to any reasonably normal power requirements.

Only by assuming a definite set of power use conditions is a comparison of these disadvantages and advantages possible. This state of affairs to a considerable degree explains the varied conclusions reached by different engineers concerning the economical feasibility of tidal power developments.

Within the range of 35 to 80% system load factors and considering the variability and uncertainty as to stream flows in dry seasons, dry years, and cycles of dry years, in other types of hydro-electric development, it appears that the advantages of tidal power installations with hydraulic power storage at least equals the disadvantages.

It is of course impossible to fix upon a specific numerical general figure as a percentage advantage to tidal power projects of the ability to know, for example, the energy output on January 25, 1973, as well as each and every day between and beyond that date. It is, however, a substantial one.

## Multiple Tidal Basins.

There are distinct advantages in having at least two tidal basins in a tidal power development. However, in many cases the topography of the estuary prohibits such an arrangement. Thus it is, that the Severn Tidal Power Development in England will be perforce a single basin one. Not only that, but the Board of Consulting Engineers on that project decided upon a single flow arrangement, that is to say, power is to be generated only while the tide is rising and a nearly equal amount of power which might be obtained while the tide is falling will not be utilized. The Aver-Vrac'h installation, however, utilizes both the inflow and outflow.

The ultimate or international development at Passamaquoddy Bay contemplates the use of two basins of which as a first step, only one basin will be constructed at the present time, but in such manner as to fit intact into the utlimate project. Thus, the first development which is recommended for immediate construction is in effect a replica on a somewhat smaller scale of the first and final Severn Tidal Power installation including utilization of the tidal flow in but one direction.

An essential feature is that the hydraulic power storage unit will be largely completed immediately and requiring but small expense to be adequate for the utlimate development. This adds a considerable amount to the cost of the initial installation which really is not properly chargeable to it. Both the Severn and the Aber-Vrac'h developments are to be built complete in one stage.

The Effect of Tidal Power Installations on Tides.

The extraordinarily high tides occurring in the Bay of Fundy and a few other places throughout the world, are due to resonant conditions existing between the natural oscillation frequency of the water in the estuary and the frequency of the tidaldisturbing force which has periodicy of approximately 12 hours, 26 minutes.

In all resonant systems the extraction of energy will tend to decrease the amplitude of motion; that is to say, cause a reduction in the tidal ranges. In the open ocean, the tidal range is only about 2 feet, while at the upper end of the Bay of Fundy it is in excess of 45 feet, so that there is a very striking pendulum effect.

An important question at once presents itself, viz., what would be the decrease in such pendulum swing resulting from abstracing energy on the order of 1,250,000 H.P.?

The answer may be approximated by mathematical analyses, but such work involves very complicated equations and assumptions only more or less exact, due to insufficient data as to cross sections of channels at various points. Accordingly the Severn Barrage committee decided to resolve this matter, so far as the Severn Project is concerned, together with a number of other features, by experimentation on a very large model.

The results obtained show that the tides are affected not only as to total ranges but as to the shapes of the tidal curves and further that the quantity of water entering the estuary with and without the proposed installation is considerably changed. This is exactly as was to have been expected.

However, the tidal range and the modifications in the shape of the tidal curve was, as a matter of percentage, very small being different with neap than with spring tides. Inasmuch as the neap tides give the smaller amount of power output they are of the most significance.

While the tidal fluctuations, the topographic configuration, and the hydraulic pendulum effect in the Severn Estuary are quite different from those in Passamaquoddy Bay and the St. Croix River, nevertheless the experiments with the Severn Model are conclusive that the total effect upon tidal curves at neap tide of the initial Passamaquoddy installation will be unimportant. The change in the total tidal range will be less than 2%.

Hydrographic studies in Passamaquoddy Bay and in the larger Bay of Fundy using the structures of the initial development would aid materially in solving this highly theoretical problem.

Complete mathematical analyses for both the Severn and Passamaquoddy regions, and comparisons of the figures for the Severn with the results obtained on the Severn model would be highly desirable from scientific considerations, especially in determining and explaining the part played by the more important factors contributing to the total result.

However, as a practical matter the extraction of 500,000 HP by the Passamaquoddy Bay project from the tides of the Bay of Fundy is insignificant compared with the natural dissipation of energy in the Bay of Fundy, which is stated by the foremost authority to have a mean value of $4.4 \times 10^{17}$ ergs per second or 59,000,000 horse power.

## Initial Installation at Passamaquoddy Bay

It seems certain that once any tidal project may be constructed in Passamaquoddy Bay, that complete development of the tidal power possibilities there inevitably will follow sooner or later. The best project for immediate construction and the one hereinafter presented, is the smallest installation which will have a reasonably high efficiency and low cost per KWH of output, except that the hydraulic power storage in the high level water reservoir cannot well be piece meal construction and should be of practicably its ultimate capacity, even though such capacity is ample for the ultimate development.

The layout of the installation recommended for immediate construction, is shown on Plate 2.

The comparative figures for the ultimate and initial installations at Passamaquoddy Bay and on the Severn Estuary are:

| | Mean Tidal Range in Feet. | Total Tidal Basin Area in Sq. Mi. | Net Power Output in Million KWH per annum. | Est. Cost. |
|---|---|---|---|---|
| Severn | 32.6 | 34 | 1,610 | 38,500,000 (<br>$186,725,000 |
| Passamaquoddy (Ultimate) | 18.5 | 139 | 2,400 | $135,000,000 |
| Passamaquoddy | 18.5 | 37 | 248 | $ 30,000,000 |

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## Power Storage System.

The power storage system for equalizing the power obtained from the tides will consist primarily of a reservoir of water, having a maximum water surface elevation of 135 feet. The plan of this reservoir is shown on Plate 2.

To create this power storage for the ultimate development, it will be necessary to obtain the ownership of 13,400 acres of land at $35.00 per acre; to build one large and several smaller dams at a cost of $2,609,000; to install electrically driven pumps, capable of elevating 12,000 cu. ft. of water per second against heads between 100 and 120 feet; and to install electric generators driven by high head turbines capable of producing 60,000 electrical H.P.

The water to be pumped into this basin will be obtained from the ocean by means of a natural channel from the Bay of Fundy to the main dam creating the reservoir. This channel is about one mile in length, and will require being enlarged somewhat to a bottom width of 200 feet.

The net energy obtainable from the water stored between the levels of 100 and 135 feet, amount to 45.5 million HP hours. The total amount of net energy storage in the corresponding reservoir of the Severn Tidal Power Project is 26,000,000 HP hours.

Power Storage Reservoir

| Elevation above mean sea level. | Area Sq. Ft. x $10^6$ | Volume Cu. Ft. x $10^9$ | Energy KWH x $10^6$ |
|---|---|---|---|
| 90 | 172 | 2.9 | 5.4 |
| 95 | 196 | 3.8 | 7.6 |
| 100 | 225 | 4.9 | 10.0 |
| 105 | 254 | 6.1 | 12.8 |
| 110 | 288 | 7.4 | 16.4 |
| 115 | 322 | 8.9 | 20.4 |
| 120 | 356 | 10.6 | 25.2 |
| 125 | 388 | 12.4 | 30.6 |
| 130 | 425 | 14.5 | 36.8 |
| 135 | 457 | 16.7 | 43.9 |

## Operation of the Passamaquoddy Bay Project

In both the ultimate and the initial installations, a part of the total energy will be delivered direct from the primary tidal plant to local users and through transmission lines to distant users; the remainder of the available energy will be applied to pumping ocean water into the power storage reservoir.

For the pumping system operating against varying head the average efficiency will be about 80% overall.

The overall efficiency of the turbo-electric units will be somewhat higher. Thus, about 66% or in round numbers, two- thirds of the power going through the power storage portion of the installation will be available for supplementing the net output from the primary tidal plant.

About 2% of the total net output of the combination will be consumed in and around the installation for operating gates, cranes, lighting, etc. It is interesting to note that this is the same plant consumption estimated for the Severn Plant.

## The Effect on Navigation

The entire Cobscook Bay would be entirely cut off from navigation unless locks be provided in one or more of the dams which will be built to turn that Bay into a tidal power basin. The cost of providing locks will vary with the size of craft for which provision might be made and no event would constitute a large percentage of the total. Provision has been made for one lock 200 feet long, 30 feet wide and with 16 feet of water over the sills at mean low water.

## Silt Deterioration

The installation would result in a larger proportion of silt entering Cobscook Bay being permanently retained there. Since the drainage basin of this bay is but 352 square miles exclusive of the bay itself; the topography rolling; and the surface very well protected against erosion by tree, brush and grass growth, the volume of silt entering the bay is quite small and the silt volume deterioration would be negligible.

The reduction of capacity in the water power storage basin would be even less.

## The Effect of the Installation on Land Drainage and Sewerage

Around the fringes of Cobscook Bay, land is of low value and there are no land drainage works which could be affected.

There is so small a population, the sewerage of which reaches this Bay, that no consideration need be given this feature, especially as Cobscook Bay would continue a salt water body so that even the element of sentiment as regards pollution of water used for potable purposes does not enter.

## The Effect of the Installation Upon Floods

The drainage area contributing to Cobscook Bay is so small and the largest stream emptying into it being but 25 miles long, the effect of the installation upon floods in these streams or around Cobscook Bay itself would be practically nil.

## The Effect of the Installation on Highway and Railway Conditions.

At the present time the shortest distance from Lubec to Eastport by highway is 40 miles, whereas the two towns are only 2 miles apart by water. The dams or causeways required to make of Cobscook Bay a tidal basin would constitute a highway between these two points and be of important economic significance not only to these towns but to the entire region.

In like manner these causeways would allow extending railroad service to Lubec and beyond.

## The Effect of the Installation Upon Fisheries

In Appendix "B" is given the report of the International Commission appointed to consider the effect on the fisheries of the International project. That Commission made no report as to the effect of carrying out only an American unit or first step of the final Development. However, in October 1929, the North American Fisheries Investigation Committee passed a resolution stating "There is no reason to expect that it (National Development) would cause any serious and widespread damage to the fisheries". Appendix "F" is a copy of this resolutic

## Effect of the Power Use on the Machine Installation

In a relatively short time it would seem that a national and to a certain extent international grid of electric transmission lines is inevitable. Probably the proposed power development on the St. Lawrence River at the northern end of New York State, will, in the not distant future, be an important element of that grid. Passamaquoddy Bay is approximately 300 miles as the crow flies to the east, and the tidal power installation there would be another element.

To be of importance in such a comprehensive plan, power centers must have very large utlimate power output capacities. Consequently, the maximum ultimate development possible at these two points are important.

The St. Lawrence River installation contemplates an ultimate output of 2,200,000 HP of which half, or 1,100,000 HP, may be used in the United States; that at Passamaquoddy Bay can ultimately be increased to the equivalent of 400,000 HP on a 100% load factor or 1,050,000 HP on a 35% load factor. Thus the ultimate tidal power project on Passamaquoddy Bay will be amply large for any such purpose.

The completion of such a comprehensive grid may be a good many years off, however, and the fairly immediate power use will probably be of a local character. Whether the grid will follow as a corollary, so to speak, of hydro-electric plant construction, or vice versa, is a question which only time can demonstrate. Indeed the sequence may well be in inverse order in different parts of the nation.

Fortunately, other than the immediate creation of the almost complete power storage unit, the Passamaquoddy Bay Project lends itself to piece-meal construction. The minimum practicable installation is, however, a large one, some things are simply so big and of such a nature that "easy steps for little feet" are impracticable.

Of course, partial developments are seldom possible at as low an installed output capacity or any other cost measure, and the one under consideration is no exception. This fact should be kept in mind in considering the initial development herein presented.

Stress must be laid on the fact that more machinery than would be needed in the immediate future is unwise, in spite of the fact that if all power generating equipment were added, the total cost per installed HP would be greatly reduced.

Until the exact nature of the demand or market for the output evolves itself, the proper generating machinery to be used cannot be forseen except in a general way. The probabilities are that a considerable proportion of the electrical output from the initial installation will be used in electro-metallurgical and nitrate-fixing operations requiring direct current at very high load factor. Certainly some power will be required for urban and rural electrical consumption, including transmission for possibly 100 miles to the north and to the west. Current for this will have to be alternating and of 60 cycles. It is possible that much of the remainder will be direct current. The development of the market will determine the ratio of installation of these two types of generation. In the case of alternating current the generator voltage will be 13,000 volts.

TABLE NO. 3

Aggregate Gross Income for First Ten Years (Applicant's Estimate)

| | | Amount | Percent |
|---|---|---|---|
| **Public Sources** | | | |
| Sale of power to public utilities (@ 1¢ per KWH) | | $11,000,000 | 29.5 |
| **Metal Plants of Project** | | | |
| Sale of Power (3 mills per KWH) | $10,866,000 | | |
| Net profit on metals | 15,320,000 | | |
| Total from metals | | 26,186,000 | 70.5 |
| Grand Total Income | | $37,186,000 | 100% |

The foregoing statements and analysis set forth the salient features of natural conditions, proposed construction, possible market and anticipated gross earnings of the project, in order to give a basis for the following discussion.

DISCUSSION

The Board has proceeded with its study, and has reached its conclusions, irrespective of any limitations that may be prescribed by Administrative regulations now in force, or of the provisions of the National Recovery Act. The Board recognizes that the Act and the rules prescribed by the President (Circular No. 1) require that "all loans to private corporations must be well secured" and that there may be some questions whether the Administration is authorized under the Act to lend money to establish the aluminum and stainless steel plants which form an essential part of this project. However, in preparing this report the Board has assumed that if the project is sound from the engineering and economic standpoints, and that, if the public good should require its construction, either the Administrative regulations, or the law, or both, might be so amended as to permit this being done.

The applicant is asking for a loan of 100% of the total cost of the project, including preliminary studies and reports, and to bear interest at 4%. No amortization of the loan is provided for in his estimates, but he has provided for depreciation of actual cost of machinery over a twenty-year period, amounting to $330,000 per year.

to utilize the stored power, water will be drawn from this reservoir through hydraulic turbines driving electric generators. The power house at Haycock Harbor, tied to the tidal power plant by a 66 kilovolt transmission line, will contain six 22,400 kilowatt hydro-electric units, a total of 134,400 kilowatts.

The following data on installed capacities, operating peak capacities, outputs, and mean loads are of value as a basis of comparison with ordinary hydro-electric developments, and with steam-electric plants of equivalent peak capacities:

Installed Capacities (Kilowatts)

| | | |
|---|---|---|
| Main Tidal Plant | 100,000 KW | |
| Haycock Harbor Equalizing Plant | 134,400 KW | |
| Total installed capacity | | 234,400 KW |
| Firm Peak Power available from both plants | | 139,000 KW |
| Mean Outputs: | | |
| On basis of 40% load factor (487 million KWH per ann.) | | 55,600 KW |
| On basis of 44% load factor (533 " " " " ) | | 60,800 KW |
| System Capacity Factor (ratio of mean power output to installed capacity) | | 23.7% or 26.0% |
| System load factor (ratio of mean power output to firm peak power) | | 40.0% or 44.0% |

Cost of Project

The plans for the project to be wholly within the United States, or "National" development of the Quoddy project, have been changed from time to time. The following is a modification of the Engineer Examiner's estimate, revised to include only the items of construction set forth finally at the hearing. This estimate eliminates certain items, such as transmission lines to the New England market, but includes the metal plants outlined at the hearing.

## Initial Development (10 Units)

| | Level of L. W. in Basin. Ft. | Level of H. W. in Basin. Ft. | Working Head. Ft. Max. | Min. | Maximum Discharge C.F.S. | Working Period. Hrs. Per Tides | Max. Output KW | Output KWH |
|---|---|---|---|---|---|---|---|---|
| Springs | -11.8 | -8.8 | 20.5 | 5.0 | 88,300 | 7.35 | 133,000 | 640,000 |
| Mean | - 9.0 | -6.4 | 16.2 | 5.0 | 82,000 | 7.05 | 101,000 | 474,000 |
| Neaps | - 7.0 | -4.8 | 12.3 | 5.0 | 78,200 | 6.30 | 70,300 | 312,000 |

## Ultimate Development

| | Level of H.W. in Upper Basin. | Level of L. W. in Lower Basin. | Working Head Ft. Max. | Min. | Maximum Discharge C.F.S. | Working Period. Hrs. Per Tide. | Max. Output KW | Output Million KWH |
|---|---|---|---|---|---|---|---|---|
| Springs | +11.7 | -11.5 | 18.8 | 5.0 | 798,000 | | 1,030,000 | 6.55 |
| Mean | + 8.6 | - 8.8 | 13.8 | 5.0 | 740,000 | 100% | 700,000 | 4.26 |
| Neaps | + 6.6 | - 7.0 | 10.0 | 5.0 | 701,000 | | 460,000 | 2.68 |

Taking 706 tides per annum, the total potential output of the generators amounts to 333,000,000 and 3,120,000,000 KWH per annum. Since the maximum output of spring tides is not completely utilized but limited to the maximum capacity of 20,000 horsepower of the generators installed, the total output actually becomes 333,000,000 and 3,100,000,000 KWH per annum, respectively.

These calculations were made on the basis of adopted turbine and generator efficiency curves.

## Hydraulic Works

These consist of sluices, turbines, locks and bridges, dams, and power storage reservoirs.

### A. Sluices.

The sluices for the basins have been fully designed, including details for hoisting and lowering machinery; operating mechanisms of all classes; and masonry constructions for the gates and for the lifting gear and other machinery. Sluices are all designed so that they can be simultaneously opened or shut by remote control.

Even the separate parts of the sluice gates, turbines, and electrical generators will be of great weight and two large cranes will be desirable for placing, repairing, and renewing them. In addition it will be advantageous to the region as a whole that railroad connections with Central Maine, now ending at Eastport, be extended over the causeway required by the initial project, to Lubec. This railroad connection is to be double track with 50 foot center line spacing. On them traveling cranes of any desired size can be operated. With the nearly 55 foot base thus possible, appliances of simple design and relatively low cost suggest themselves.

## B. Turbines

Since every tidal power scheme calls for the developing of power under widely varying heads, the type of turbine which may be installed is strictly limited. Those which will generate alternating current should operate at constant speed and all turbines have as high an efficiency as practicable.

The machines decided upon are 26'5" in diameter, 40 revolutions per minute for the alternating current portion of the installation, and running at constant speed under heads varying from 5 to 24 feet head is 91 per cent; at 16 feet, 93 per cent; and at 5 feet, 71 percent.

## C. Locks and Bridges.

The navigation lock will be 200 feet long, 30 feet wide, and with the sills - 25.5 feet elevation referred to mean sea level.

Since the highway and railway traffic will be much more important than that through the lock, provisions have been made to carry the former over both and the latter over one end gate.

## D. Dams.

The methods of constructing the dams between Eastport and Lubec, including the deep water channel between Treat Island and Eastport, have been given special consideration.

Careful study of the geological conditions obtaining here, together with soundings and core examinations, definitely show the bottom to consist of native rock overlaid with several feet of stiff blue clay, on top of which is several feet of soft slimy material. It appears that in no case is this latter soft material more than 10 feet deep and at most places considerably less.

The blue clay underneath this surface slime layer is unusually stiff and solid and apparently is the same as that which above water in the neighborhood, stands with vertical sides or banks for long periods of time.

Over such a foundation it is intended to deposit, either from scows or from trestles with the use of railroad trains, ridges of quarry run rock. By quarry run rock is meant rock just as it comes from the quarry when broken up by a vast system of tunnels, at varying elevations, loaded with black powder and set off simultaneously by electricity. By proper spacing of tunnels, amount and character of explosive, etc. it is possible to dislodge up to 1,000,000 cu. yds. at one blast and be assured that few individual pieces will be too large for handling by modern steam shovels, of say 1 cu. yd. in volume.

There are numerous places in the immediate vicinity where enormous quantities of rock can easily be obtained in this way. The closest rock mass to the work is Treat Island which is nearly at midlength of the dam. There will also be a supply available from excavation for the various structures.

After placing along both the up stream and down stream toes of the main dam, ridges or dikes of quarry run rock extending from shore to shore on the Bay bottom, a mixture of sand and gravel would be deposited on the sides of these quarry run ridges which face the center of the dam. This material would settle into, and in large measure fill the interstices of these quarry run ridges. Thereafter the space between would be filled with clay, by suction dredges.

All the foregoing materials would be deposited under water.

When the top of this underwater construction should be evened up to a depth of say 50 feet, a 4 pile, 16' bent, 3 stringer railroad trestle would be built in each edge of the clay center, and the same method of construction carried on as before.

Obviously, no difficulty can be encountered in this sort of work until the entire structure may be raised to within say 20-25' of the low water level. By the time this is done the sluice gates will be completed and through their use the maximum difference in elevation on either side of the dam will not exceed 10 feet, and this difference will be reduced to zero four times in 24 hours.

The completion of the remaining and higher portions of the dam with such differences in water level on the two sides, will, of course, offer less difficulty than the closing of the break in the Colorado River by the Harriman Railroad interests in 1907.

In that closing the final difference in elevation of the water on the two sides of the dam was 13 feet and closing an opening 1,000 ft. wide was actually made in slightly less than 14 days, and the total displacement of the material due to the swift current was found to be very small. Details of this construction with practically no difficulties whatsoever are given in the paper, "Irrigation and River Control in the Colorado River Delta" Transactions American Society Civil Engineers, Vol. LXXVI, pp. 1204-1571 pp. 1364-78.

The total volume of quarry run rock will probably be 3,334,000 cu. yds.; of sand and clay, 500,000 cu. yds.; and of hydraulic dredge deposited clay, 2,000,000 cu. yds. Based upon the personal experiences in this exact type of work, of some members of this Commission, the following unit costs have been fixed:

| | |
|---|---|
| Quarry Run Rock | $1.64 per cu. yd. |
| Gravel and Sand | $0.50 per cu. yd. |
| Clay | $0.10 per cu. yd. |

In depositing these materials they will undoubtedly compress, displace, and sink into and through the layer of slimy soft material on the Bay bottom. Very soon a final landing will be made on the stiff clay and thereafter the construction will have practically no settlement other than that due to the re-adjustment and settlemrnt of the quarry-run rock fill. The settlemtnt of such material placed in water will be slight and piecemeal and will continue here and there for months.

The final result will be a causeway which should be approximately 75 feet wide on top. This width results from the consideration that there should be on the causeway a roadway of at least three 8 feet lanes for automobiles and trucks, or say, a width between curbs of 25 feet; a sidewalk for pedestrians; and two railroad tracks, one on either side of the foregoing and each requiring an 18 foot road bed width.

With the winds in certain directions, combined with spring tides, waves of considerable magnitude, say possibly up to 5 feet, would strike the causeway from the ocean side. On account of the disagreeable result of spray falling and freezing on the roadway, there should be approximately 25 feet of width on the ocean side of the causeway top of quarry run rock extending up say three feet above the general causeway top level.

On account of the slight settlemtnt which will occur for perhaps a year or so, paving of the roadway and side-walks should be deferred for about that length of time.

Once the settlements cease, the cause-ways or dams will be permanent constructions with little or no maintenance expense. The amortization of course would be solely that of obsolescence.

## E. Power Storage Reservoir

The power storage reservoir will be created by several minor earth filled dams and a major one of concrete 120 feet high. For the initial installation these structures will be constructed for maximum water surface elevation 15 feet below that desirable for the ultimate project. All have been planned with the view of increasing their heights, such 15 feet, and their final cost will be very little more than if built to the final elevations initially.

The cost estimates of the immediate installation include all of the land necessary which will ever be needed and this involves buying about 13,400 acres. The total area of the high water surface in the initial reservoir will be 8170 acres, and the estimates include clearing that amount of land at once.

The main dam has been designed with a straight gravity cross-section, but it is probable that considerable saving may result from using a multiple arch dam.

The Area and Capacity of Storage for Various Water Depths are as Follows:

| Elev. Water Surface above M. S. L. | Area in Acres | Energy Stored Above Elev. 100.0 in Million HP Hrs. |
|---|---|---|
| 100 | 5170 | |
| 110 | 6610 | 8.6 |
| 120 | 8170 | 20.4 |
| 130 | 9720 | 35.9 |
| 135 | 10500 | 45.5 |

## Electrical Machinery

As already pointed out some of the machinery will be direct current and some alternating current. In all cases apparatus will be of standard and well known types with nothing peculiar about them. Consequently, their costs are based on those of actual installations as well as manufacturer's figures, and are quite definite.

## Obsolescence and Depreciation

The obsolescence and depreciation of both the ultimate or international one or the initial projects require consideration from two distinct standpoints, viz. (1) the summed obsolescense and depreciation of the separate important features, and (2) of the projects taken as unities.

The causeways or dams will, except for minor settlements of especially the quarry run material, during the first couple of years, be entirely permanent constructions.

The tidal basins they will create will gradually be diminished in effective capacity by deposition of silt, and their ultimate destiny will be that of all surface water impounding reservoirs, viz. complete destruction from such cause. However, the contributing water sheds are relatively quite small and unusually well protected from erosion by heavy forest, underbrush, and grass growths.

At least at present, and doubtless for many years to come, the use of the water shed for cultivated agriculture is quite small. Consequently the silt content of the relatively small quantities of fresh water entering the several tidal basins will be low. Even a considerable part of such silt will be carried out to sea by operative flushings, although to a smaller extent then under natural conditions.

Hence the life of the tidal basins based upon siltation could not be less than 800 years, and in any event much longer than almost all large water storage basins in the United States heretofore constructed or under consideration.

Thus the tidal basins including the causeways or dams forming them, taken per se will have almost negligible obsolescence and depreciation.

The life of the power storage reservoir, would be even greater than that of the tidal basins and on the order of at least 500 years, because very little surface water would enter it and even that with a low silt content, while the salt water constantly flushing it would be practically silt free. The earth retaining dams would be permanent and there could be very little deterioration.

The concrete work comes in a different category. The disintergregation of concrete in sea water is quite similar to that due to frost conditions. The crystalization out of solution of the salt contents of sea water has much the same effect as the crystalization of ice particles upon artifical and natural stones. Consequently the best method of protection is prevention of interior crystalization through rendering the stone as impermeable as possible. The simplest plan of doing this is by an impermeable coating.

Gunite is an easily applied and extraordinarily dense sand and cement concrete mixture which will absorb only about 5% of water by volume, that is to say, approximately the same as granite. Furthermore, its adherence to concrete surfaces is so great as to be practically incorporation.

Application of a thin veneer of gunite over all concrete surfaces in contact with sea water will greatly, and probably entirely, obviate all depreciation from such source. Experience in coating of concrete piles in salt water piers on the Pacific Coast during recent years indicate that the protection will be complete.

Nevertheless, conservatism suggests the useful life of concrete work at Passamaquoddy Bay be taken at 75 years.

In another class is steel and cast iron work. By thorough-going maintenance in the form of coating, it would seem that the life of all such work should be at least equal to that in the halls of steel ocean going steamers, and experience indicates this to be at least 50 years.

Another important element is the hydraulic machinery. Obsolescence rather than depreciation would probably be the controlling factor. As to this it is significant to note that while it is almost exactly 20 years since turbines were installed in the Keokuk power plant on the Mississippi River, that the plans for the hydraulic machinery in both the Severn Tidal Power and the initial Passamaquoddy Bay project are essentially the same as the Keokuk plant. Changes in large low-head turbine design are nevertheless probable but the possible range of efficiency improvement is small since existing efficiencies are higher than 90 per cent.

Accordingly, it would appear conservative to take the life of the large unit hydraulic machinery to be installed as 40 years.

Similarly while changes in large unit electrical apparatus is practically certain, yet the efficiencies of the units which will be installed is in no case less than 95 per cent. It is improbable that such efficiency could ever be increased to more than 99% and no one would exchange old equipment for new to obtain an increase of only 4% efficiency, prior to the time when the absolute maximum possible plant power output would be vital. Even then, the necessity would probably be of such a nature as to indicate a much more radical treatment. Such considerations irresistably point to adoption of a useful life of at least 40 years, the current practice to take shorter periods notwithstanding.

Incidentally one must not lose sight of the fact that in the case of public utilities properties, large depreciation allowances, that is to say, short useful lives, are urged because these result in higher annual depreciation and obsolescence charges passed on to the consumers. This means increased gross annual receipts.

The proper annual payments into an obsolescence and depreciation fund which would result from using the herein above determined useful lives for the several elements of the Passamaquoddy Bay Tidal installations might collectively be less than would result from considering the possible obsolescence and depreciation of the projects as unities. That is to say, that instead of considering only the probable useful lives of the several important classes of construction works independently, it is necessary also to consider the installations as a whole.

The reason for this is that technological advances in energy production may conceivably supplant hydro-electrical energy sources by something now little more than dreamed of.

For example, cheaper power may conceivably be obtained from the direct heat of the sun; from heat obtainable at great depths below the earth's surface; from waves; from atomic energy; from chemical reactions; from radical changes in internal combustion prime movers, etc.

Furthermore, wireless transmission of power is perhaps more than a possibility, and anything of that sort would radically affect the location of power producing centers.

These things are seldom considered in this connection but when one recalls the sequence of unexpected and tremendous changes which have occurred in communication within little more than the past century; the ox-cart, the canal boat, the steam railway, the electric railway, the internal combustion transportation power units, the aeroplanes, the telegraph, the telephone, the radio, etc., he is impressed with the reality of possibilities for future changes.

In addition to these technological considerations there are sociological ones such as habits of life and modes of thought, shifts of population masses, etc.

Lastly, there are possibilities of radical destructive elements such as deliberate destruction during wars, earthquakes, subsidences or elevation of coastal land masses, etc.

On the other hand, at least one thing seems clear in this rapidly changing world, and that is that mechanical power will never be of less significance in civilization than it is at present and probably increasingly greater for at least a considerable time to come.

Taking all these elements into consideration, it is suggested that the useful life of the Passamaquoddy projects as entities be taken as not greater than 100 years.

Comparative figures made from these two points of view show that the annual obsolescence and depreciation allowances <u>on a straight line basis</u>, are for the initial installation $300,000 as an entity, and

$386,700 for the collected elements.

## Maintenance and Operation

Installations of this character and magnitude are usually placed in operation a section at a time, and adjustments, rearrangements and "clean up" work continues for at least a couple of years. This period constitutes the twilight zone between construction and maintenance and operation. During this time all such expenditures are better classified construction as has been done in preparing the cost estimates of the initial project.

Thereafter the total maintenance and operation costs, including replacements, supplies, repairs, administration, etc. will certainly not exceed $350,000 per annum.

## Alternative Hydro-Electric Opportunities

A correlative matter of interest in the Passamaquoddy Bay project is the cost of hydro-electric power which may be developed at other places in Maine and throughout the United States generally. In the well known so-called "308" reports of the United States Army Engineer Corp; the report of the President's Committee on the Water Resources of the United States in 1934; numerous other Governmental, State and Public Utilities Reports; and the several appendices attached to this report, the essential features of hydro-electric power opportunities in various parts of the United States have been set forth. Perhaps the latest data in respect to hydro-electric insulations in Maine are contained in the Report of the Maine Passamaquoddy Commission which has just been completed.

All these sources of information, and particularly the records of stream flow gauging issued by the Water Resources Division of the United States Geological Survey, have been examined.

It is impractical to set forth in this report even the essential features of such investigations which were carried out as aids to judgment in connection with the Passamaquoddy Bay projects, not so much because of their volume as because of the confusion which their technical intricacies would cause in lay minds.

Hydro-Electric Opportunities in Maine

It is generally understood that Maine almost heads the list of States as regards hydro-electric opportunities. Nevertheless, it seems evident that over half of the feasible water powers of the state have been developed already, and that a considerable percentage of the remaining opportunities may never be utilized because of their remote location, lack of dependable flow, or excessive cost.

It is obvious that the last large scale hydro-electric installation in the state, completed in 1930, on the Kennebec River near Bingham, was at least as attractive as any existing when it was begun.

Certainly it was decided upon only after exhaustive investigations.

## Wyman Plant at Bingham

This has a present installed capacity of 88 thousand horsepower which will be increased to 102 thousand horsepower by addition of an additional turbine generator when the demand may require it. The total cost to date has been $13,000,000.

Careful analysis of stream discharge data as far back as available, viz. 1893, shows that the dependable output of this plant is distinctly less than the total installed capacity owing to the variability in stream flow. The following table sets forth the pertinent facts as regards output and the cost of power obtainable at the outgoing bus bars.

### Table

In a year of average flow with present installation.

| | | Kilowatts | KWH |
|---|---|---|---|
| Prime (90% of time) | | 10500 | 92,000,000 |
| Secondary | | 17000 | 149,000,000 |
| | Total | 27500 | 241,000,000 |

Cost per prime kilowatt $= \frac{13,000,000}{10,500} = \$1240.$

There may be other opportunities on Maine rivers for which the corresponding figures would be less but if so they are relatively small or less favorably located, otherwise one or more of them would have been first developed. Therefore it is safe to take the foregoing figures as the optimum ones for Maine.

## Other Large Plants in the United States

As a matter of fact Maine's hydro-electric resources are exceeded in numerous other parts of the country, if considered solely from the standpoint of relative generating cost. Perhaps the most outstanding examples are Boulder Dam, Nevada; Bonneville and Grand Coulee, Washington; Fort Peck Dam, Montana; Muscle Shoals, Tennessee, and the St. Lawrence River just over the Canadian Line.

At Boulder Dam some 850 kilowatts can be developed at all times and the total installed capacity will be 1,365,000 KW, so that if the $109,000,000 total cost of the entire project, which also will furnish a regulated flow for irrigation and flood control, be charged to power, the cost per installed KW capacity will be $79.00.

At Grand Coulee the ultimate cost will be about $181,000,000 and the ultimate installed capacity 1,900,000 KW, again charging all the costs against power; or $95.00 per KW.

At Bonneville the ultimate installed capacity will be 516,000 KW and the estimated cost $70,000,000 or about $135.00 per installed KW, if all the cost be charged to power.

At Fort Peck the United States War Department is constructed the project primarily to improve navigation on the Missouri River. The ultimate installed capacity of the power generating machinery will be 300,000 KW and total cost $86,000,000.

For Muscle Shoals the figures for the revised plans are not yet available.

Of course some of these extremely low cost power installations are quite remote from centers of population, and will produce much more power than the present market is absorbing. This is only another form of expressing the fact that hydro-electric power opportunities are not ideally located. Large additional investments will be required for long and expensive transmission lines with their resultant operation losses.

In passing it is important to note that the reason why the Far West plants are so inexpensive is that they are either in mountainous regions where streams have steep gradients, or, in the case of the Bonneville run-of-the-river power, because of important stream regulation resulting from widely varying climatic conditions in various portions of the drainage area.

The best regulated stream of importance in the Eastern states is the St. Lawrence, due to the tremendous natural storage of the Great Lakes, but it drains a vast low-lying plain instead of mountainous masses, consequently its gradient is flat.

In other words, in the Far West it is often small flows, capable of even over year regulation in relatively small reservoirs, coupled with high heads; and in the East large flows and low heads. Due to its high degree of natural regulation, the St. Lawrence River is doubtless the outstanding opportunity for large scale hydro-electric power development east of the Rocky mountains. The total cost of the proposed American development there is $110,000,000 and the total installed capacity of the generating units 1,100,000 HP (run-of-the-river plant). The output will drop down to 720,000 HP at low stream flow.

Making proper allowances for the difference in uniformity of power output, Passamaquoddy Bay energy will be cheaper then that at the St. Lawrence installation.

## Output Costs at Alternative Fuel Electric Plants.

Another correlative matter of interest is the cost of developing energy at Passamaquoddy Bay by a fuel burning plant.

This Commission has exhaustively investigated this feature and has been led to the conclusion that the methods of analysis adopted by the English Severn Barrage Committee are the most easily understood and followed by non-technical readers.

The total output at Passamaquoddy Bay, after power storage, is 2,400,000,000 KWH. An analysis of the prospective load curve shows that it may be used in the following manner:

| Loadfactor | KWH | Cost in mills per KWH if produced by steam. | Tot. Cost if produced by steam. | Comparative unit steam costs as computed by Severn Commitee Mills Per KWH. |
|---|---|---|---|---|
| 80 | 1,200,000,000 | 4.16 | 4,992,000 | |
| 40 | 700,000,000 | 5.93 | 4,151,000 | 6.0 (34% l.f.) |
| 23 | 250,000,000 | 7.90 | 1,975,000 | |
| 15.25 | 150,000,000 | 10.17 | 1,525,000 | 13.58 |
| 10 | 100,000,000 | 13.80 | 1,380,000 | 19.24 |
| | 2,400,000,000 | | | |
| | Total annual cost with a steam plant | | $14,024,000 | |
| | Cost per annum at Passamaquoddy Bay | | 9,139,000 | |
| | Annual saving over equivalent steam Plants | | $ 4,885,000 | |

(Above costs are with money at 4% and no taxes)

"Taken from Federal Power Commission report given as Appendix "D".

Market for Output of the Passamaquoddy Bay Plant

The smallest installation which is feasible at Passamaquoddy Bay would have an annual power output capacity at the tidal plant of 333 million KWH. This is about half the electrical consumption in all Maine during 1933. Some time will be required before such an addition to the region's power output will be absorbed except as the simple existence of such cheap and peculiarly dependable and flexible power will create a market for itself of heavy high load factor power using industries.

Such a state of affairs is an inevitable concomitant of carrying out great hydro-electric power installations even though they may lend themselves to piece meal construction as only a minority of them do. For example: "Upon ultimate completion of the Bonneville and Grand Coulee power projects now under construction, 2,366,000 kilowatts of new capacity, equal to approximately twice the present installed capacity in the tributary market areas, will be available for future requirements"*.

The tributary area around G,rand Coulee and Bonneville extends about 200 miles and within it the present power use is about half the existing capacity. That is to say, the output will be about six times the present consumption.

Such a state of affairs with huge power installations is due to the very nature of the case; power demands will not warehouse themselves like goods accumulating until they constitute a ship's cargo.

Immense projects require years to build and during such periods important economic and technological conditions may well occur. Rarely, if ever, can advance contracts for large blocks of power be secured from substantial interests prior to the time when actual power deliveries may be made. The Boulder Dam development is the outstanding exception but even here it was necessary for the Federal Government to finance a $250,000,000. community enterprise in order that a power customer for 35 percent of the output might be created.

(*"Development of the Rivers of the United States". Preliminary Report of the President's Committee on Water Flow. House Document No. 395. 73rd Congress. 2nd. Session pp348.)

If a natural resource of this class is ever to be utilized, one single great step is inevitable <u>sometime</u>; the only question is when.

The development of these several great power opportunities in the West and South just at this time was determined in large part by the social and economic conditions now obtaining. Investigations by this Commission disclose the fact that the urge of such conditions is at least as great now in Maine as they ever have been in any portion of the nation west of the 99th meridian, or in the Tennessee Valley.

Before passing to this feature it may be well to point out that doubtless the entire output of the Passamaquoddy Bay installation would be fully absorbed before that at any of the other plants mentioned, except that on the St. Lawrence River. This is because Passamaquoddy Bay is on the Atlantic sea coast, within a relatively short distance back from which is more than a third of the nation's total population; it has an ice free excellent port; it is the nearest point of the United States to Europe and Africa; it has an ample supply of high type labor in its vicinity; and it is well situated with respect to a national electric transmission grid. These and other minor advantages together would more than offset a 15 to 20 per cent KWH price handicap.

<u>Sociological Conditions in Maine</u>

Until a few decades since, Maine had a strong position in the United States. It's lumber resources, its sea coast harbors, its maritime position, and its fisheries were vitally important in the national life. Until after the Civil War no one could have forseen any relative diminution in the importance of these elements.

One of its two great resources, lumber, is almost entirely exhausted, to a distinctly greater degree than the gold and silver deposits of the West. In its wake is a vast area, embracing about 80 per cent of the state which has practically no lumber and yet is not cleared for cultivated agriculture, a sort of non-descript forest growth of value only for paper pulp and household fuel. Its sea coast and harbors have been rendered of little account by the switch from wood to steel and from said to steam driven vessels, and by preferential railroad rates to Atlantic harbors further south. Its maritime advantages have turned to near ashes. Changing national food habits combined with increasing disparity in living standards of the world's fisher folk, have gravely reduced the importance of fisheries. The increasing mechanization of American farms, to which Maine conditions lend themselves to an almost minimum degree, capped the climax. It was literally a case of being smitten hip and thigh.

In the face of much grave reverses of fortune, the general attitude of Maine's citizenry is an astonishingly stubborn conviction that advantage can and will be taken of future changes which are regarded as quite as certain to occur as those in recent decades, and that the retrogression recently experienced will be first counteracted and then reversed. In other words there is the conviction that the pendulum in human development swings to the right as well as to the left. There is not even the hint of an exodus to a more promising land, but only a tightening up of the belt to take up the slack from lean days and a renewed determination to fight it out on the home ground.

There is no question, however, but that civilization and social institutions in Maine are undergoing a crisis. In spite of its hereditary self reliance, Maine is the 3rd state in distress relief; the 33rd in its per pupil expenditures on common school education; the 33rd in its wage scale for teachers. There is a need which is critical for outside help in this trying period which the prevailing germ-plasm, reliance and spirit of the population justify the hope that it will not be long.

It would seem to be at least as desirable to hold such a civilization intact until it finds itself again, as it was to rebuild, and to a larger degree construct de novo, the civilization west of the Continental divide, and to reconstruct social institutions in large areas by such enterprises as the Tennessee Valley Authority.

Even considered from the sole standpoint of cash outgo and income to the National Treasury, the help extended to the West has paid well. When the boom days of Leadville, Darango, Cripple Creek, Tonopah, Virginia City, the Mother Lode, and the hydraulic mining on the Feather, Yuma and American rivers were over, civilization in the West sagged, and it was helped over its slump and into a far more glorious era than ever by Federal expenditures for irrigation. The base of irrigated agriculture has added to itself so many things that the foundation of them is appreciated by but few. But in the last analysis some $200,000,000 at no interest and 40 years repayment period has directly and indirectly resulted in so developing nearly a third of the United States that the annual contribution to the Federal Treasury from that region now totals $300,000,000.00 per year.

This time it is the extreme north eastern corner of the nation which needs some of the same kind of help which it joined in extending during the recent past. How seriously? In what way? To what extent?

To Maine Quoddy Commission's Report contains much information concerning the present state of affairs in Maine. A few pertinent facts will set forth the matter more clearly and succinctly than a mass of statistical costs.

The gross value of agricultural products in 1933 of the entire state of Maine was $58,043,000, or almost exactly the same as that from Imperial Valley, California, with an area of but 480,000 irrigated acres and a total population of only 60,000.

Much more than half of Maine's agricultural crop value comes from potatoes in Aroostook County. Sometimes this crop is profitable and sometimes results in severe losses depending upon a quite variable market. The cost of production is roughly $1.00 per barrel, while the return this season has been about 60¢. The total population of the potato growing district is 100,000 and the total area in potatoes is 160,000 acres. Approximately but one sixth of the area within this state is devoted to cultivated agriculture.

The largest single source of income to Maine is from toursits and residents during the short summer season. The figure is determined by the Maine State Planning Commission at $85,000,000. annually. This is less than twice the value of the agricultural output from the aforesaid Imperial Valley in California.

In the matter of wood pulp, the competition from Canada is so severe as to suggest the question of whether the area of uncleared land in Maine might not better be conserved from the standpoint of tourist and summer outing business and for re-creation of its original lumber wealth.

While size is a thing very generally overestimated by most Americans, nevertheless a practical stand-still in population under modern American conditions is a significant if not a sinister feature. In the recent redistribution of Congressional representatives, Maine lost 25 per cent of its quota.

## How May Assistance be Rendered?

If Maine needs help in its present crisis, how may it be extended? A dole for cash distribution to the people in need is at the very best but a temporary expedient with practically no helpful effect upon sociological and economical institutions. A quite usual form of Federal assistance has been large contributions towards highway construction. This has been carried to such an extent that Maine has a satisfactory system of highways even considered from the standpoint of its tourist business. Furthermore highways once built must be maintained; they produce no direct income but do cause direct and constantly increasing maintenance costs. If its civilization were opulent Maine might very well have a much larger mileage of paved roads, but to appreciably extend the existing net work would be comparable to financing a pretentious home for a man who needs money to pay taxes and buy food, and the running of which is beyond him.

Another form which Federal assistance often takes is construction of post-offices, customs houses, etc. These again when completed are not bread winners, but like paved roads are really liabilities in a sense.

The ability to generate vast amounts of dependable, flexible and cheap power is a tremendous asset to any community of people, and its relative importance so far as can now be seen will continually increase for a long time to come.

By such process of exclusion it seems clear that the most effective kind of help which might be extended by the federal Government to any considerable area in New England, would be developing plants capable of always turning out large blocks of cheap hydro-electric power.

Indeed power will be for the New England district what irrigation has been to the West. Man is living less and less by bread alone, or put in another way, more and more by the output of the machine. To an increasingly greater degree is the importance and social significance of manufacturing. To it must a growing percentage of the population devote itself and not only that, but the growth of such percentage is itself increasing. The basis of manufacturing is dependable power at a cost the traffic will bear, just as the basis for development of the arid west was dependable irrigation at a cost western institutions could bear.

No one can doubt that the state of Maine would have been a much more populous one if it had been underlain by a great field of good quality coal. White coal, if cheap, will doubtless do for Maine what it has done in Italy and Scandanavia.

It is a case of irrigation in the west, white coal in New England.

## Extent of Assistance Desirable

With respect to the extent of assistance needed it certainly should be at least all that the Passamaquoddy Bay Project would afford.

The cash cost of relief in Maine for the first nine months of 1934 was $5,531,000 which the Federal Government contributed $3,037,000, the state, $431,000 and local bodies $2,063,000. Corresponding figures for the entire year will probably be at least a total of $7,500,000, of which the Federal Government's portion would be approximately $4,100,000.

The matter of immediate import is the extent of relief through employment; the power generating capacity would be the permanent result.

These two considerations are somewhat antagonistic, at least for the immediate present, in that the amount of employment relief seriously needed in Maine within the next three years is very large, whereas until the power market creates itself and grows beyond the capacity of the smallest feasible initial development, the least money spent now the better.

The smallest feasible initial unit of the piece-meal construction of the ultimate project will require in direct labor between 20 and 25 million man hours and indirect labor 14 to 17 additional million man hours. Of the indirect labor approximately one half would be in Maine and most of the remainder in the heavy industries districts of the Pittsburgh and/or Chicago areas. Assuming the average wage scale to be 60 cents per hour, the total wage payments would be $12,000,000 to $13,000,000 direct labor and $8,400,000 to $10,200,000. for indirect labor. The total sum would thus be about 70 per cent of the total cost.

Certainly all of that amount which would go into Maine is seriously needed and it is even desirable that the sum should be greater.

While the Commission is convinced that the type of power which would be generated by the project and the cost at which it could and should be sold, will create a market for itself in a relatively short time, it recognizes the fact that there are many uncertain factors in the present economic, and sociological conditions in the United States as a whole and in New England in particular, and that it may be preferable, for the time being at least, to stop with the suggested initial development until its power output shall be absorbed. Comments as to the rapidity with which the power market will develop have been set forth elsewhere.

## Location of a Relief Project

Conceding that Maine is in serious need of assistance at this time; that such assistance should take the form of constructing hydro-electric power installations; and that the extent of the help demands expenditures on the order of $30,000,000., the next question which suggests itself is what are the best opportunities within the state for such installation?

Several considerations at once suggest themselves. The first is relative cost of the power outputs. Another is that interference with the existing status quo should be a minimum, because more than half of the water power possibilities on Maine streams are already developed. A third consideration is that the more important remaining hydro-electric power possibilities are interespersed among existing plants and are often controlled by one of the three outstanding public utilities of the state. Further, the undeveloped power sites are relatively small and so scattered as not only to require joint use of or a considerable duplication of power transmission lines, but would mean much more expense and difficulty in supervising between 20 and 25 million man hours of local labor.

Happily the first consideration of output cost decisively resolves the question as elsewhere set forth.

The Tidal Project's Effect Upon
Income from Tourists.

An important element in the entire matter is the amount of assistance which carrying out of the Passamaquoddy Bay Project would afford is the repercussion it would have upon the State's tourist business.

First would be the creation of a highway between Eastport and Lubec only two miles long to replace going all around Cobscook Bay, a distance of 40 miles by the paved road. This shortening of the distance to Quoddy Head is enough to materially increase the number of visitors to that eastermost point of the United States.

Of much more importance would be the installation itself, a thing unique, and of outstanding magnitude. At first thought it may seem a bit far fetched that a man created installation would materially add to the combined natural attractions of the State for tourists. The studies of the Maine State Planning Commission and the data which it has submitted necessitates a serious view of the matter.

It finds that the increase of tourist expenditures within the State would be $10,000,000 of which at least 15% would be net income, or $1,500,000 which capitalized even at the rate of 10% per annum represents an asset of $15,000,000. This is indeed a significant sum the magnitude of which is so great as to demand serious consideration when balancing the pros and the cons of the whole subject.

## The Construction Cost of the Project.

The total cost of the recommended initial installation at Passamaquoddy Bay is as follows:

| | |
|---|---|
| Tidal Basin including Dams, Power House, Navigation Locks, Highway, and Railroads Over them, etc. | $9,782,000. |
| Sluice gates, including all concrete work incidental thereto | $3,248,000. |
| Hydraulic Electrical Equipment of Tidal Power Plant | $6,518,000. |
| Power Storage Reservoir complete including land, dams, and concrete work | $5,340,000. |

| | |
|---|---|
| Storage Unit Hydraulic-Electrical Equipment | $3,737,000. |
| Transmission line | $1,500,000. |
| Total | $30,125,000. |

Annual Electrical Output

The net saleable energy output of the initial development will be 250 million KWH per annum. There will be no secondary power.

The initial development may be increased by 20,000 HP steps up to the capacity of the basin merely by addition of the necessary mechanical and electrical equipment and without any increase in the dams, basin, or concrete structures. This will increase the net saleable energy from 250 to 430 million KWH. Or in other words the power output may be increased 74% at an increased cost of $11,000,000 or 36%.

An increase of output with such increased machinery installation could be secured by changing the development into a two basin one, further increasing the net annual output to 606 million KWH, no secondary power, and still further reduction in KWH cost.

The net output of the ultimate development will be 2,400 million KWH per annum. Again there will be no secondary power.

Thus the ultimate installation will cost 4.5 times the initial one and have 9.6 times as much output.

The additional cost of completing the ultimate possible development will be $105,000,000.

Hence the enlargement of the initial installation to the ultimate one would involve scrapping no elements built, and the total cost of the ultimate installation would be $135,000,000.

## Costs at Which Power May be Sold

If the Passamaquoddy Bay installation be constructed as a Federal project on the same basis as Federal irrigation projects in the West, i.e., repayment in 40 equal annual installments beginning when the status quo is established, no interest, and no sharing of construction costs by incidental benefits, the total annual expenses and charges until full Federal reimbursement would be:

| | |
|---|---|
| Maintenance and Operation | $350,000 |
| Annual Payment<br>2½% of 30,000,000 | 750,000 |
| Total | $ 1,100,000 |

If the entire output were marketed at a single rate, this would be for the full use of 250 million KWH, 4.4 mills. A much more probable marketing would be:

| | |
|---|---|
| 40% or 100 million KWH averaging 3 mills | $300,000 |
| 40% or 100 million KWH averaging 5 mills | 500,000 |
| 20% or 50 million KWH averaging 7 mills | 350,000 |
| | $ 1,150,000 |

If a total of $10,000,000 be considered as chargeable to improved transportation facilities, increase of tourist income, and emergency relief work in Maine, thus reducing the amount chargeable to power to $20,000,000. the average unit rate would be 3.4 mills for the full use of 250 million KWH; and the more probable marketing:

| | |
|---|---|
| 40% or 100 million KWH averaging 3 mills | $300,000 |
| 40% or 100 million KWH averaging 4 mills | 400,000 |
| 20% or 50 million KWH averaging 6 mills | 300,000 |
| Total | $ 1,000,000 |

A serious misconception of the significance of these power rates will result unless it be kept in mind constantly that none of the above power output is secondary. Comparing the foregoing figures with those for partly firm and partly secondary power is impossible. As an aid to judgment, however, the cost of Boulder Dam power delivered to seaboard at Los Angeles will be 4.4 mills per KWH.

## Probable Immediate Market

(A) Rural and Urban Market:

Within a radius of 100 miles of the project there are six countries where the present per capita consumption of power is low. With an aggressive management, as recommended by the Commission, a market of 50,000,000 KWH can be obtained in this region.

(B) Local Industrial Market:

Chemical. A reliable chemical concern manufacturing a diversified line of products has shown a strong interest in a block of 90,000,000 KWH of a high load factor character and at a price of 3 to 4 mills per KWH.

One of the raw materials used by this company is Malagash Salt located 60 miles from the project.

Fertilizer Production. Aroostook County uses 150,000 tons of fertilizer per annum which is mostly imported. A substantial portion of the nitrogen and phosphate constituents of this tonnage can be most cheaply manufactured at Passamaquoddy. In addition, manufacturers advise that the Atlantic seaboard as far south as Norfolk, Virginia, will come within a favorable freight rate zone for Passamaquoddy.

The unit for phosphoric acid, as considered by these manufacturers, is 15,000 KW demand which will consume 105,000,000 KWH at a price of 3 mills. The raw materials for this product will come by water.

The energy required for nitrogen alone will be 45,000,000 KWH.

Metallurgical.

The Maine State Planning Board give in their report the various possible uses of power in metallurgy. Only aluminum and alloy-steels will be considered here.

Aluminum can be produced at the project site for 13 cents per lb. of ingot. The present market price is 22.9 cts. per lb. Correspondence has been received offering the delivery by water of the necessary raw materials.

Regarding the necessity of a competitive source of aluminum reference is here made to Hon. Joseph B. Eastman's letter attached as Appendix G.

<u>Alloy-steels:</u> Investigations of prices for power now being paid by manufacturers of alloy-steel situated on the North Atlantic Coast shows a wide differential in favour of Passamaquoddy. A 50 ton plant producing 15,000 tons of alloy-steel per annum will consume 37,000,000 KWH. The rapid increase in the use of these alloy-steels assures Passamaquoddy of an ultimate tonnage many times the initial.

<u>Pulp and Paper:</u> Inquiries have been received from local mills for 10,000,000 KWH. As matter of interest, a pulp and paper mill recently built and located on tidewater in Maine now uses 100,000,000 KWH yearly.

The specific items of the market are then:

| | |
|---|---|
| Rural and Urban | 50,000,000 KWH |
| Chemical | 90,000,000 |
| Phosphoric Acid | 105,000,000 |
| Nitrogen | 45,000,000 |
| Aluminum | 216,000,000 |
| Steel | 37,000,000 |
| Pulp and Paper | 10,000,000 |
| Total | 553,000,000 KWH per annum. |

"For Cooper Charter see Exhibit      of this
Report.
(Appendix "A" to Report of Eastport District)

"This appendix deleted in this report (Appendix "B" to Report of Eastport District.) See House Document 300, 73rd Congress, 2nd Session."

APPENDIX "C"

# BOARD OF REVIEW

Re: DOCKET NO. 1641 REPORT — March 30, 1934.

TO: Colonel H. M. Waite, Deputy Administrator

FROM: BOARD OF REVIEW

| | |
|---|---|
| Applicant: | Dexter P. Cooper, Inc., Eastport, Maine, a private Corp. (Maine) |
| Project: | Tidal Power Plant, Equalizing Plant, also Aluminum and Stainless Steel Plants. |
| Location: | Passamaquoddy Bay and Haycock Harbor, near Eastport, Maine |
| Cost: | $47,000,000, including Aluminum and Stainless Steel Plants, but excluding trunk transmission line. |

| | |
|---|---|
| State Engineer | :Tentative report, outlining special concessions in financing (see below) |
| State Advisory Board | :Concurred in tentative report of State Engineer |
| Federal Power Commission | :Disapproved |
| Legal Division | :No Report |
| Engineering Division | :Disapproved |
| Finance Division | :No Report |

## INTORDUCTION

This application was submitted to the State Engineer (P.W.A.) for Maine, September 11, 1933. His report, dated October 5, 1933, stated, "A project of this character cannot stand an interest rate of 5% or even 4% and that 50% of theobligation cannot be amortized in ten years". He then outlined a tentative program of financing on a 2% basis for a period of 50 years, expressing the opinion that the project would not prove feasible on any more rigid terms.

At the request of the Public Works Administration, made on October 20, 1933, the Federal Power Commission made an investigation of this project. The report of their Chief Engineer is dated January 2, 1934.

This report states in substnace that "Quoddy" power is not cheap power. It is possible, under very favorable assumptions, with money at 4% and no taxes, that the switchboard cost of power would be 5.63 mills per kilowatt-hour. On this basis, with a 40% Load Factor, steam electric power could be developed in approximately that same location at a cost of 5.93 mills. At 80% Load Factor, which might be obtained with the proposed electro-metallurgical plants, the cost to generate with steam would drop to 4.16 mills while "Quoddy" power would remain at about 5.63 mills per kilowatt-hour. It would be impossible to sell "Quoddy" power in the metropolitan area of Boston because of the prohibitive cost of transmission, which would amount to some 3.15 mills per kilowatt-hour, based on money at 4%.

The report states also that the original outlay for the Quoddy development (for installed capacities see page 6) without transmission lines (and without the proposed aluminum and stainless steel plants but as set forth by the report of the Federal Power Commission), would be $48,878,000 while the initial outlay for the steam plant of 35,000 kilowatts capacity would be about $4,000,000. A steam generating plant of capacity equal to Quoddy would cost $16,000,000. (These figures are calculated with capital costing 6%.)

The Commission believes it possible that existing unused water powers in Maine could be developed more cheaply than "Quoddy" power. Also that this development could be carried on in steps which the market could more easily absorb.

The report points out that no market now exists for the proposed great block of "Quoddy" power, and the cost of this power is too high for the use of the proposed electro-chemical and electro-metallurgical operations, as compared with the cost of power available in other localities. The Federal Power Commission's conclusion accompanying its report dated January 2, 1934, is "that it cannot recommend approval of the application".

Report by theEngineer Examiner (P.W.A.) dated March 16, 1934, recommended disapproval on the ground that the project is economically unsound.

Endorsements and Objections

The project has received many endorsements, which are a part of the record. The following extract from a telegram from Governor Brann of Maine is an indication of the tenor of these endorsements:

"I believe it is the almost unanimous belief in Maine that favorable action on the development of the Passamaquoddy Project will do more to relieve unemployment presently and provide industrial prosperity eventually for Maine and New England than any other individual project."

The New England Council has reported the following resolution as having been passed at its meeting in Hartford, Connecticut, March 16, 1934, with reference to the Passamaquoddy Bay Tidal Power Project:

"Resolved: That the New England Council, assembled in its 34th Quarterly Meeting, hereby records itself as opposed to the use of approximately $40,000,000 of the Federal funds for the development of the so-called Passamaquoddy Bay Tidal Power Project, as an example of unsound economic principle."

A hearing before the Board of Review was held March 30, 1934. There were present at this hearing the following:

Board of Review
F. H. Fowler, Chairman of Hearing
H. Abbot
R. S. Buck
M. L. Emerson
C. W. Ham
Ole Singstad

Representing P.W.A. Administration
Col. H. M. Waite, Deputy Administrator
Carey H. Brown, Acting Chairman, Board of Review
H. T. Hunt, General Counsel
W. H. Herring, Engineer, Miss. Valley Committee
D. W. Rose, Engineer, Federal Project Division
Michael Straus, Director, Press Section
Gerald Egan, Press Section
R. S. Tatlow, Administrative Division

Representing the Examining Divisions

| | |
|---|---|
| Legal | J. J. O'Connell, Jr. |
| Financial | T. J. Walsh |
| | Foster Adams |
| | K. S. Wingfield |
| Engineering | A. L. Sherman |
| | F. P. McKibben |
| | B. F. Thomas, Jr. |

Representatives of Other Government Offices
Roger B. McWhorter, Chief Engineer, Federal Power Commission
H. C. Smith, Assistant Chief Engineer, Federal Power Commission
Oswald Ryan, General Counsel, Federal Power Commission
A. C. Bruce, Engineer, Federal Power Commission
W. G. Mervine, Chief Mechanical Engineer, Nat'l Power Survey, Fed. Power Com.
R. S. Dean, Bureau of Mines
Douglas Whitlock, representing N.R.A. (Attorney, Assoc. of Manufacturers in the Aluminum Industry.)

For the Applicant
Senator F. Hale, of Maine
Senator W. H. White, of Maine
Congressman E. C. Moran, 2nd District of Maine
Congressman John G. Utterback, 3rd District of Maine
Frederick A. Delano
Dexter P. Cooper, President of Dexter P. Cooper, Inc. at Eastport, Maine
M. B. Pike, Assistant to Mr. Cooper

Representatives of the Press
Elizabeth M. Craig, Press Herald, Portland, Maine
Ruby Black, Evening News, Portland, Maine
R. B. Marbut, Associated Press
J. C. Henry, Providence (Rhode Island) Journal

Also Present
C. H. Nelson, Bangor, Maine
E. D. Finnegan, Bangor, Maine
J. D. Utterback, Bangor, Maine
J. A. Ferris, President, Chamber of Commerce, Eastport, Maine
M. K. Murphy, Eastport, Maine
Miss A. M. Miller, Eastport, Maine
Mrs. Swett, Eastport, Maine
Paul Brockett, National Academy of Sciences, Washington, D. C.
J. H. Payne, Westinghouse Electric & Manufacturing Company

Applicant

The applicant, Dexter P. Cooper, Incorporated, is a private corporation, authorized in 1925 by a special act of the Maine Legislature, Chapter III of the Private and Special Laws of 1925, approved April 11, 1925. This incorporation was subject to a referendum vote by the people of the State of Maine and was approved by the voters at an election held in September, 1925. The corporate existence of the company began on October 28, 1925. The incorporators were Dexter P. Cooper, Gertrude S. Cooper, F. A. Havey, of Eastport, Maine, and K. H. Bennett, of Lubec, Maine.

This corporation was authorized to develop and utilize the power of the tides in the Bay of Fundy at, or near, Eastport and Lubec, Maine; to acquire all necessary rights in Maine and New Brunswick, to erect dams, locks, power houses, etc.; to transmit and distribute electric energy; to transmit electric power out of the State of Maine; and other necessary functions.

Quoddy Tidal Power Projects

The Bay of Fundy and Passamaquoddy Bay region has long been recognized as one of a few localities scattered throughout the world, where extremely high tides, coupled with favorable topographic conditions, offer exceptional opportunities for large tidal-power development. On each change of tide tremendous volumes of water flow into and out of these large land-locked harbors through narrow inlets and passages between islands, while the topography allows the construction of the extensive system of barriers, dams, and gates that are necessary in such development. The very obvious possibilities of this development have long commanded general public interest. To date, no major tidal-power development has been completed either here or elsewhere, although several have been intensively studied and at least the preliminary steps have been taken toward such developments on the Severn River in Great Britain.

The Quoddy Projects have varied in extent, according to different plans that have been developed at various times.

The most extensive one, called the "international project", contemplates the complete use of the entire tidal power available in both arms of the bay, together with an equalizing auxiliary power plant and storage reservoir 12 miles to the southwestward, and including transmission lines extending as far as the Boston region, with a storage reservoir and peak load plant near the south end of the transmission line.

The "National Project", here contemplated and applied for, is limited to development of the western branches or United States section of the bay, the equalizing storage reservoir and power plant 12 miles to the southwestward, aluminum and stainless steel plants in the immediate vicinity of the power plants, and a sub-station near the plants through which power will be delivered to the existing public utility companies serving the six eastern counties of Maine (for distribution through their lines within a radius of about 100 miles).

The principle of the development proposed for this project, known as the two-basin single flow sump system, consists of impounding water in large basins at two different levels so that electric power can be obtained by the flow of water from the upper into the lower basin through turbines. The upper basin is fitted with filling gates; the lower basin, with emptying gates. The two basins are separated by a dam containing the power house. The action can be demonstrated by following the operation during a complete tidal cycle.

Assume low tide: The lower basin has been emptied of water down to the level of the low tide. The emptying gates are now closed, the filling gates on the upper basin also being closed. The tide now begins to rise. The filling gates on the upper basin remain closed until the tide reaches the level of the water in the upper basin. The filling gates are then opened and remain open until the crest of the tide is reached, when they are closed before the tide begins to ebb.

Throughout this cycle, water is flowing from the upper basin through the power house producing power continuously, but with an ever-changing head upon the turbines. The head is continuously changing because the level of the water in each of the two basins is continuously changing due to the flow through the turbines, and due to the flow through the emptying gates and filling gates while open. As the tide ebbs, the emptying gates remain closed until the level of the sea is as low as the level in the lower basin; then they are opened and the lower basin is discharged until the turn of the tide at low tide.

Description of Proposed Quoddy Development

The present project consists only of that portion of the ultimate development located within the United States.

The lower pool is formed by the construction of a dam from Lubec to Dudley Island; from Dudley Island to Treat Island; and from Treat Island to Estes Head on Moose Island (Eastport). The emptying gates are located in the dam between Dudley Island and Treat Island. A lock for the passage of vessels is incorporated in the dam between Lubec and Dudley Island. The separation between the lower and upper basins is by a dam running from Denbow Point across Cobscook Bay past Mathers Island into Carryingplace Cove, where the power house, filling gates and some of the emptying gates are located. The neck of land on Moose Island between Carrying place Cove and Johnson Cove is to be excavated so that the tide may enter from the Western Passage of Passamaquoddy Bay. A second set of filling gates for the upper pool are located across Bar Harbor.

The power house consists of a structure for twenty-two units, only ten of which would be installed initially. Each unit is a 17,500 horsepower hydraulic turbine directly connected to a 10,000 kilowatt generator, arranged for out-door installation. The present plans include the use of hydraulic turbines having moveable guide vanes and having a speed of 40 R.P.M. Since the original drawings were made, the development of the Kaplan adjustable blade turbine has been accomplished and this turbine will greatly increase the efficiency of the plant. The tidal range varies from 12.5 feet to 27.0 feet; and the effective head on the turbines varies from 24.0 to 5.0 feet.

As essential adjunct of the project as now contemplated is the provision for storage of power, accomplished by means of a large reservoir 120 feet above sea level to be located at Haycock Harbor 12 miles southwest of the tidal power plant. During the period of the tidal cycle when a surplus amount of power is available at the tidal power plant, water will be pumped from the ocean to this reservoir by means of electrically driven centrifugal pumps. During the period when it is desired to utilize the stored power, water will be drawn from this reservoir through hydraulic turbines driving electric generators. The power house at Haycock Harbor, tied to the tidal power plant by a 66 kilovolt transmission line, will contain six 22,400 kilowatt hydro-electric units, a total of 134,400 kilowatts.

The following data on installed capacities, operating peak capacities, outputs, and mean loads are of value as a basis of comparison with ordinary hydro-electric developments, and with steam-electric plants of equivalent peak capacities:

Installed Capacities (Kilowatts)

| | | |
|---|---|---|
| Main Tidal Plant | 100,000 KW | |
| Haycock Harbor Equalizing Plant | 134,400 KW | |
| Total installed capacity | | 234,400 KW |
| Firm Peak Power available from both plants | | 139,000 KW |
| Mean Outputs: | | |
| On basis of 40% load factor (487 million KWH per ann.) | | 55,600 KW |
| On basis of 44% load factor (533 " " " " ) | | 60,800 KW |
| System Capacity Factor (ratio of mean power output to installed capacity) | | 23.7% or 26.0% |
| System load factor (ratio of mean power output to firm peak power) | | 40.0% or 44.0% |

Cost of Project

The plans for the project to be wholly within the United States, or "National" development of the Quoddy project, have been changed from time to time. The following is a modification of the Engineer Examiner's estimate, revised to include only the items of construction set forth finally at the hearing. This estimate eliminates certain items, such as transmission lines to the New England market, but includes the metal plants outlined at the hearing.

## TABLE NO.1

| | | | |
|---|---|---|---|
| Preliminary Expense ........................................ | | | $500,000 |
| Land and rights-of-way ........................................ | | | $869,000 |
| **Constructions** | | | |
| **Tidal Power System** | | | |
| Emptying gates and lock, Lubec to Eastport ........................ | $2,206,000 | | |
| Dam and filling gates to Bar Harbor ........................ | 358,000 | | |
| Dams and gates at power house ........ | 13,408,000 | | |
| Power house structure, excavation, gates, etc. .................. | 2,894,000 | | |
| Power house discharge gates .......... | 679,000 | | |
| Power house equipment ................ | 4,670,000 | | |
| Total | | $24,215,000 | |
| **Haycock Harbor Equalizing Plant** | | | |
| Power storage reservoir, complete ...... | 3,904,000 | | |
| Storage power house and equipment ...... | 4,359,000 | | |
| 66-kv transmission line from storage power house to main power house ........................ | 1,254,000 | | |
| Total | | $9,517,000 | |
| **Miscellaneous** | | | |
| Highway and railroad relocation, etc. | 318,000 | | |
| Omissions and contingencies .......... | 3,498,000 | | |
| Total | | $3,816,000 | |
| Total Construction .............. | | | $37,548,000 |
| Engineering ........................................ | | | 1,454,000 |
| Legal and Administrative ........................................ | | | 129,000 |
| Interest during construction ($20,000,000 for 2½ years @ 5%) .... | | | 2,500,000 |
| Estimated total cost of Tidal and equalizing plants .............. | | | $43,000,000 |
| **Metal Reduction Plants** | | | |
| Aluminum smelter, 40-ton capacity @$80,000....... | | 3,200,000 | |
| Stainless steel plant, 50-ton capacity @$16,000 - | | 800,000 | |
| Total cost of Smelters (including overheads) ............ | | | 4,000,000 |
| Grand Total for Project .............................. | | | $47,000,000 |

The applicant did not include in his estimate of cost of the power plants any item for interest during construction, but such an allowance has been added in the above estimate based on a two and one-half year construction period as planned by the applicant. (The Federal Power Commission is of the opinion that it would take three and a half years to complete this entire project). On the other hand, the Board assumes for the purpose of this report that the estimated cost of the aluminum and steel plants allows for interest during construction.

It should be noted that if the "National" project is considered as a preliminary step to the development of the "International" project, it will be necessary at the time of changeover, to eliminate certain gates and a very large part of the dam then separating the two pools, because the "National" upper and lower pools would then be made into one pool. This would necessitate writing off the cost of such abandoned works (a large part of item of "dams and gates at power house", $13,408,000 in Table 1, plus other smaller elements of cost).

Applicant's Estimated Market for Power

An analysis of the applicant's estimate shows that the total power produced for the first ten years of operation would be distributed as follows:

TABLE NO. 2

| | | |
|---|---|---|
| **Use by Public** | | |
| To public utilities for distribution | | 21% |
| **Use by Metal Plants of Project** | | |
| In the manufacture of aluminum | 60% | |
| In the manufacture of stainless steel | 18% | 68% |
| **Unsold** | | 11% |
| Total | | 100% |

Applicant's estimate of Gross Revenues

An analysis of the "Financial Statement for Initial (National) Development" gives the following anticipated sources of total revenue for the first ten years of operation:

TABLE NO. 3

Aggregate Gross Income for First Ten Years (Applicant's Estimate)

| | | Amount | Percent |
|---|---|---|---|
| Public Sources | | | |
| Sale of power to public utilities (@ 1¢ per KWH) | | $11,000,000 | 29.5 |
| Metal Plants of Project | | | |
| Sale of Power (3 mills per KWH) | $10,866,000 | | |
| Net profit on metals | 15,320,000 | | |
| Total from metals | | 26,186,000 | 70.5 |
| Grand Total Income | | $37,186,000 | 100% |

The foregoing statements and analysis set forth the salient features of natural conditions, proposed construction, possible market and anticipated gross earnings of the project, in order to give a basis for the following discussion.

DISCUSSION

The Board has proceeded with its study, and has reached its conclusions, irrespective of any limitations that may be prescribed by Administrative regulations now in force, or of the provisions of the National Recovery Act. The Board recognizes that the Act and the rules prescribed by the President (Circular No. 1) require that "all loans to private corporations must be well secured" and that there may be some questions whether the Administration is authorized under the Act to lend money to establish the aluminum and stainless steel plants which form an essential part of this project. However, in preparing this report the Board has assumed that if the project is sound from the engineering and economic standpoints, and that, if the public good should require its construction, either the Administrative regulations, or the law, or both, might be so amended as to permit this being done.

The applicant is asking for a loan of 100% of the total cost of the project, including preliminary studies and reports, and to bear interest at 4%. No amortization of the loan is provided for in his estimates, but he has provided for depreciation of actual cost of machinery over a twenty-year period, amounting to $330,000 per year.

From the evidence available to the Board, it appears that the applicant's assets consist of its charter from the State of Maine; that its owes certain interests for the cost of the series of plans and reports that have resulted from its preliminary engineering studies. These studies are stated to have cost about $500,000. The Board assumes this amount includes the cost of securing the charter of the company. This amount is slightly in excess of 1% of the estimated cost of the project. Testimony was introduced at the hearing which showed that these preliminary expenses are included in the estimate covering the proposed loan, and that the applicant has the option of reimbursing the public utility or commercial interests that have supplied the funds for them, thus leaving thepproject free of all incumbranse. The record does not disclose the terms of this option, nor does it clearly show what type and degree of control would be exercised by the interested contributors to the original studies, if the option to buy them out is not exercised.

For the purpose of this report, the Board has accepted the applicant's estimate of cost, modified as already stated. However, such acceptance does not constitute approval of the proposed designs, unit costs, or of program of construction. These could be approved only after a much more thorough study including investigations at the site. This project, when undertaken, will be a pioneer in major development of tidal power and therefore will naturally be subject to uncertainties that always accompany pioneer work, especially because of the construction of submarine dams of almost precedented height under severe tidal flows. The Board is of the opinion that some of the unit prices may be too low, that a more generous allowance should be made for contingencies, and that a longer period than estimated by the applicant should be allowed for construction. Also a more detailed study of the most suitable dam design, under the adverse conditions that will be encountered, will be desirable. However, these questions are merely left open and have not influenced the Board in reaching its conclusions.

## Relation to Power Market

The Board has considered at length the relative economic advantages of "Quoddy" power as compared with production of an equal amount from hydro-electric sources on the rivers of Maine, and as compared with power produced from a steam electric generating plant located on tide water at Eastport or anywhere between Eastport and Boston. The comparison is unfavorable to "Quoddy" power.

Detailed reports by the War Department and by the Federal Power Commission, show large power resources still available on the Kennebec and Penobscot Rivers. The War Department reports also show that several groups of these could be developed at a lower unit installed cost than could "Quoddy" power. More detailed studies in the report of Murray and Flood on Water Power Resources of Maine show that cost per kilowatt hour for firm power from the most advantageous selection of sites on these two streams would be less than the cost of "Quoddy" power delivered either to the Maine market, or to the southern New England market.

In regard to Quoddy generating cost as compared with steam electric generating cost, the estimates made by the Federal Power Commission, the costs given in the St. Lawrence River report published by the State of New York in 1931, and detailed operating data for a number of large steam-electric stations available, to theBoard, show that with 4% money and low load factors, "Quoddy" power will be approximately of the same cost as steam generation at Eastport, and that with higher load factors, and with delivery at any other point than in the immediate vicinity of the plant, the cost of Quoddy power will be higher than power from steam.

An important item in connection with these steam electric and hydro-electric developments competitive with Quoddy is that they may be brought in more nearly at such time and in such amounts as are required by the growth of load on the systems, instead of having to be almost completely developed at the outset, and having to wait a number of years, even under most favorable assumptions, for full absorption of the output.

Relation to Metals Manufacture

The applicant's plans for construction of the aluminum and stainless steel plants appear not to have been worked out in as great detail as his plans for the hydro-electric development, but in this case, also, the Board has accepted them tentatively.

Without the proposed aluminum and stainless steel plants, the project would be absolutely dependent on wholesaling power to existing public utilities or on serving sparsely populated territory not now reached by existing systems. Theoretically, the establishing of plants for the manufacture of two different metals, provides a diversified market that should be a valuable factor in the success of the project; actually, the value of this factor is problementical and most difficult to evaluate.

The essential part that the two metallurgical plants play in the program, although they cost but $4,000,000, or less than 10% of the total loan requested, may be seen in Tables No. 2 and No. 3 of this report, which show that they furnish anticipated market for 68% of the electric power, and are expected to contribute over 70% of the gross revenues for the first ten years of operation. Without these metallurgical plants, the entire project is admittedly not economically justified. It appears to the Board that the paramount objection to this proposed program is that its entire successdepends on the profits of these two industries that will have to be developed from the ground up, both in manufacturing and in marketing.

The manufacture of aluminum in the United States, apparently is concentrated in the hands of one company, and the basic patents, details of the methods of manufacture, and actual manufacturing costs are not available. While some of the basic patents have expired, patents for modifications are understood to be still in force. As a result the applicant may be hampered in his attempts to establish an aluminum plant and in the opinion of the Board will certainly be delayed beyond the estimated time in bringing the plant to full production. The applicant's estimate that he can produce the metal, at a cost to him of about 50% of the present market price, is open to question, since no authentic production costs are available, and also since the cost will depend on the manufacturing methods adopted and these methods have not yet been determined.

As regards the stainless steel plant, more information is available, the manufacturing processes are not so closely controlled, and the applicant's plans seem to be further advanced.

The public desirability of additional capacity and of competition, particularly in producing aluminum, has been strongly urged by the applicant, and seriously considered by the Board; but whether this is the most economical place for such development is open to question. The applicant states that he has had no previous experience in the manufacture of these metals. The plants and the distribution of their output are a business that must be built up in the face of strenuous competition from some of the largest organizations in this country, who have spent many years and large sums of money in research and in perfecting their manufacturing methods, who now have a large and successful sales organization, and who might be unusually jealous of and antagonistic to such competition. It seems quite evident that full profit from the metal plants could not be realized during the first year of operation as has been estimated by the applicant.

No evidence presented to the Board indicates any physical or economic reasons why such metal plants would be more successful in Quoddy than in any other well chosen locality along the northeastern Atlantic Coast. The applicant claims one special advantage, namely, shorter sea haul from Europe for raw materials. In the opinion of the Board, a few hundred miles less sea travel would have but little effect on the cost of marine rates and any such small saving which might be effected on this item might be more than offset by higher freight rates on finished products to the domestic market. The special advantage claimed for locating the metal plants at Quoddy is the low cost of electric power, but in the section immediately above, this factor has been shown to be unfavorable to Quoddy.

SUMMARY

The Board recognizes that under the natural conditions at the site, a definite amount of power can be made available here each year, affected only by the amplitude and recurrance of the tides, and not affected by droughts or floods as is the case with many hydro-electric projects. It is true also that upon the definite determination of construction and operation costs for this project the costs per kilowatt hour output can be closely determined.

On the other hand the Board is of the opinion that the cost of power to be generated by the facilities proposed is not low as compared with certain existing and prospective hydro-electric plants, or as compared with the production of energy by steam based on present costs of fuel at this same location. However, if the cost of fuel increases, either because of higher production costs, or because of depletion of fuel supply, and as the available more economical hydro plants are developed and utilized, the time may arrive when the development of this project will be economically sound.

CONCLUSION

1. The Board concurs in general with the conclusions and recommendations of the State of Maine Advisory Board, the State Engineer (PWA), the Engineering Division of the Administration, and the Federal Power Commission.

2. The Board is of the opinion that, from an economic standpoint, the time has not yet arrived for the development of this project.

RECOMMENDATION

The Board recommends that the application be denied.

Frederick H. Fowler, Acting Chairman

Hunley Abbott

Clifford W. Ham

Richard S. Buck

Ole Signstad

Merton L. Emerson

APPENDIX "D"

FEDERAL POWER COMMISSION
Washington

January 3, 1934.

The Federal Emergency Administrator
of Public Works,
Washington, D. C.

Dear Sir:

In accordance with the request of the Federal Emergency Administration of Public Works in letters of October 20, 1933, signed by Deputy Administrator Henry M. Waite and of October 21, 1933, signed by Major R.W. Crawford, Executive Assistant, the Federal Power Commission has investigated as fully as possible the application of Dexter P. Cooper, Inc. for a loan of $43,000,000 with which to construct a tidal water-power project in Passamaquoddy Bay at Eastport, Maine (P.W.A. Docket No. 1641)

After a careful consideration of all available data, including information and estimates submitted by the applicant, and numerous conferences with the applicant's representatives and engineers, the results of which are summarized in the report of our Chief Engineer attached hereto in triplicate, the Federal Power Commission finds that the project would not be self-liquidating and cannot, therefore, recommend approval of the application.

The docket in this case is returned herewith.

Very truly yours,

FEDERAL POWER COMMISSION

By Frank R. McNinch
Chairman

FEDERAL POWER COMMISSION

WASHINGTON

Report on the Application of Dexter P. Cooper, Incorporated to the Federal Emergency Administration of Public Works For a loan of $43,000,000 for the construction of a Tidal Power Project at Eastport, Maine.

MEMORANDUM FOR THE COMMISSION:

1. Reference is made to letter dated October 20, 1933, from Deputy Administrator Henry M. Waite, and letter dated October 21, 1933, from Major R. W. Crawford, Acting Director of Projects Division, Federal Emergency Administration of Public Works, referring to this Commission for investigation, report and recommendation, the application of Dexter P. Cooper, Incorporated, for a loan of $43,000,000 with which to construct a tidal water-power project in Passamaquoddy Bay at Eastport, Maine. The application is designed by the Public Works Administration as Docket No. 1641, and is practically identical with project No. 463 on the records of this Commission, commonly known as the "Quoddy" project.

2. The project first came before the Commission on a much larger scale, including originally the development of tidal power on both sides of the international boundary---in the State of Maine and the Province of New Brunswick. The original application for preliminary permit was filed January 2, 1924, by Dexter P. Cooper, and another application for preliminary permit was filed December 3, 1925, by Dexter P. Cooper, Incorporated. The Commission issued a preliminary permit for project No. 463 on May 28, 1926. The permittee filed an application for license on October 22, 1928, with the Commission's field representative (the District Engineer, War Department, Boston, Massachusetts), and the application, together with the report of the Chief of Engineers, United States Army, thereon, was received by the Commission on May 16, 1929. The application contemplated initial and ultimate installations of 464,000 horsepower and 1,087,000 horsepower.

3. The applicant filed a revised application on September 16, 1929, eliminating those parts of the projects lying within Canadian territory, thus confining the project to the United States. The project as thus revised contemplated an initial installation of six generating units with aggregate capacity of 80,000 horsepower, and an ultimate installation aggregating 240,000 horsepower. Ultimately this revised project was to include a pumped storage plant at Haycock Harbor on the coast of Maine about 12 miles southwesterly from Eastport, but this feature was not to be included in the initial construction. At that time the cost of the initial development was estimated by the applicant as $16,809,000.

4. Under date of September 19, 1933, the applicant submitted to the Commission what it termed supplementary information and data pertaining to the project, which constitutes a substantial change in the scope of the initial development, and a radical revision of cost estimates. The project, as modified by this last revision, is identical with that now before the Federal Emergency Administration of Public Works. The initial installation in the main power plant at Eastport would be 10 units of equal size, having aggregate wheel capacity of 175,000 horsepower and generator capacity of 100,000 kilowatts. At the Haycock Harbor plant the total initial turbine capacity would be 180,000 horsepower and the generator capacity 135,000 kilowatts. Provision would be made for future installation of 10 additional units in the main plant, having the same capacity as the original 10 units. The main, or parent, plant would be connected with the Haycock Harbor pumped storage plant by a transmission line. The initial project also includes a transmission line extending from the generating station to Tewksbury, Massachusetts, about 20 miles northwest of Boston. The applicant gives the length of the transmission line as 287 miles, but it is probable that its length would exceed 300 miles. It is not entirely clear, however, from the wording of the application for loan whether the applicant has fully decided that the transmission line will be necessary, since it appears that hope is entertained for sale of the power to new industries in the vicinity of Eastport.

5. Attached hereto is a small general map showing the layout of the proposed project works, including the power storage plant, but not including the long-distance transmission line. Cobscook Bay would be closed off from the open sea by a series of dams extending northerly from the town of Lubec to Moose Island, on which Eastport is located, and thence northwesterly to the mainland. The large water area thus set off would be divided into an upper pool or forebay, and a lower pool or tailrace, by a dam extending from the upper end of Denbow Neck to Moose Island. The power house would be located at the Moose Island end of the latter dam, and would utilize the water for the generation of power as it passes from the upper to the lower pool through the turbines. A group of large gates installed in the dams, would be used to refill the upper pool at each successive high tide; and another group of gates, appropriately located, would be used to empty the lower basin at each successive low tide. The draft of water from the upper pool and its discharge into the lower pool would tend to equalize the pool levels and thus reduce the power head; but a head sufficient for practical operation in the production of power would be maintained at all times. The plans also provide for a series of auxiliary gates to be used at certain tide stages in by-passing the discharge from the draft tubes directly to the ocean, thus conserving head and increasing the plant output at critical tide stages.

6. The tidal range, or difference between successive high and low tides, at the project varies between 12 feet at neap tide and 27 feet at spring tide, and, of course, variation of power will occur not only as a result of head variation but also because of the consideration that with

smaller heads between pools, less water can be exchanged before equalizing to the limiting minimum head. It is evident, therefore, that with any given installation of hydroelectric machinery, the available energy and capacity would fluctuate widely in each tidal cycle. In order to correct this great power fluctuation, the applicant proposes to construct the power storage plant at Haycock Harbof to which reference has been made. The Haycock Harbor site was chosen for the storage reservoir because of its favorable topographical features. A portion of the energy output from the main plant would be delivered to a pumping station at Haycock Harbor and used to pump sea water into the reservoir, the normal maximum surface elevation of which would be 120 feet above mean sea level. The water thus stored would be used as required through hydroelectric equipment installed adjacent to the reservoir, with forebay at reservoir level and tailrace at sea level. Thus, it is possible by operating the main plant and the power storage plant together, to obtain a uniform supply of power from the project. Pumping capacity of 120,000 horsepower would be installed at Haycock Harbor, and provision would be made for increasing the generating capacity in the pumped storage plant to conform with ultimate enlargement of the main plant.

7. The principal structure included in the "main plant" of the project are rock-fill dams, power house, filling and emptying gates, and navigation lock. Large volumes of earth and rock excavation would be required in the vicinity of the power house and upper pool filling works. The sites of the power house and filling gates, and a large part of the material to be excavated, could be inclosed by cofferdam, so that the work might be performed in the dry. The material to be excavated is earth, sand, and solid rock. It is believed that the quantities, as reported by the applicant, may be accepted as correct for present purposes; but that as to unit-prices, there is more uncertainty. Some modification of the applicant's proposed unit prices is suggested, as will appear hereinafter.

8. The proposed concrete structures include power house, navigation lock, and gate structures, and are probably of adequate design, although no complete check of the design has been made in this office. All of these structures would be subject to the action of salt water, which in some instances has caused rapid deterioration of concrete. Special precaution would, therefore, be necessary to obtain concrete of very high quality. Possible deterioration of this concrete should receive consideration in estimating annual depreciation.

9. The dams or barriers would consist essentially of huge rockfill dikes, backed on the high-water side with heavy deposits of earth. Both earth and rock would be obtained from the excavations previously mentioned. The dams would be built by dumping the material from scows, rehandling being necessary only for the upper portion of the dams, above dumping range. Generally speaking, the dam construction, as well as the excavation, would be performed by heavy machinery handling large quantities of material at comparatively low unit cost.

10. At certain stages of the dam construction, the dumping operations would be subject to difficulties from high current velocities, making very accurate placing of material impossible. Such difficulties would no doubt result in excessive excavation yardage.

11. Drawings submitted by the applicant indicate that solid rock is available for the foundation of all structures, although the exact nature of the rock is not shown. Three diamond drill borings in the general vicinity of the power house and filling gates indicate a red shale formation at the surface and extending to a depth of more than 20 feet. It is believed that this material would provide a suitable foundation for the structures in question.

12. The applicant has presented estimates of cost and output, which are summarized as follows:

| | |
|---|---|
| Annual output . . | 487,000,000 kilowatt-hours at plant switchboard |
| Annual output . . | 438,000,000 kilowatt-hours if delivered to Boston area. |
| Prime capacity . . | 139,000 kilowatts at generating plants |
| Prime capacity . . | 125,000 kilowatts if delivered to Boston Area |
| Cost of project works (Main plant and Haycock Harbor Storage Plant) ............... | $39,871,000 |
| Cost of transmission line to Tewksbury, Mass. ........ | 18,282,000 |
| Total ..... ..... | $ 58,153,000 |

13. Attached hereto is a photostat copy of the applicant's revised estimates. These estimates have been reviewed insofar as practicable. The unit prices used by the applicant for earth and rock excavation, including the placing of these materials in the dams, are ostensibly on the basis of quotations contained in letters from two contracting firms. One of these letters quotes a price of $1.64 per cubic yard for rock excavation, and 51 cents per cubic yard for earth excavation, plus 26 cents per cubic yard for all earth and rock requiring rehandling. The other letter quotes a price of $2.75 for rock excavation and 35 cents for earth excavation. The prices furnished by both contractors were intended to cover both the excavation and dam construction; that is, the unit prices were supposed to cover theearth and rock excavation and the placing of these materials in the dams. While the unit prices placed upon the different classes of excavation varied rather widely, it appears that the aggregate cost of both earth and rock excavation would be about the same under the two proposals. By this statement it is meant that if the same quantities are used in the two proposals, the total cost would be about the same, notwithstanding difference in unitprices. The applicant adopted the lower price quoted in the two letters for each class of excavation. Perhaps a more logical course would have been to use one contractor's quotations throughout, or to have taken the average of thepprices quoted for each class of excavation.

14. The applicant's unit price for rock excavation is $1.64 per cubic yard. The average of the quotations in the letters referred to is $2.20. It is believed that the applicant's price should be increased to $2 per cubic yard. The applicant's unit price of 35 cents per cubic yard for excavating earth and placing it in the dams is regarded as adequate, except that it is proposed to add 26 cents per cubic yard for rehandling approximately 6,000,000 cubic yards of earth and rock. The applicant's unit price for lightly reinforced concrete, requiring expensive form work, is from $8.50 to $9 per cubic yard. This price has been increased to $10 per cubic yard. The effect of these changes is to increase the applicant's estimate of cost by $4,015,000, thus raising the total estimated cost of the project works, exclusive of long-distance transmission and exclusive also of interest during construction, to $43,886,000.

15. The applicant has expressed the opinion that the project could be constructed in a period of 2-1/2 years. This period is regarded as too short, since the quantities involved are very great and the necessary sequence of operations indicates a rather extended construction period. It is believed that 3-1/2 years will be required for construction of the works, and this period has been adopted for estimating purposes.

16. In estimating the cost of the project, the applicant did not include interest during construction. It is here assumed that the plant would be constructed, if at all, with funds obtained at a commercial rate of 6-1/2 percent interest, or with funds supplied by the United States at 4 percent interest. At the 6-1/2 percent rate there would be added to the estimate for the project works, exclusive of transmission line, for interest during construction, the sum of $4,992,000; and at the 4 percent rate, the sum of $3,072,000.

16a. It is assumed that 1-1/2 years would be required for construction of the 300-mile transmission line. At the 6-1/2 percent rate, interest during construction would increase the estimated cost by $891,000; and at the 4 percent rate, by $548,000.

17. The estimates of cost, as increased to take account of changes in unit prices, and to include interest during construction at both the 6-1/2 and 4 percent rates, are as follows:

| | 6-1/2% Interest | 4% Interest |
|---|---|---|
| Project works, exclusive of long-distance transmission line ................ | $48,878,000 | $46,958,000 |
| Transmission line to Tewksbury ............... | 19,173,000 | 18,830,000 |
| | $68,051,000 | $65,788,000 |

18. The annual charges on the project have been estimated on the basis of both 6-1/2 and 4 percent interest rates, as follows:

## Estimated Annual Charges
## Interest at 6-1/2%

### Project Works Exclusive of Transmission Line

#### Fixed Charges

| | | | |
|---|---|---|---|
| Interest on capital cost 6-1/2% on $48,878,000 | $3,177,000 | | |
| Taxes on capital cost 1-1/2% on $48,878,000 | 733,000 | | |
| Depreciation on machinery and concrete structures 1-1/2% of $24,500,000 | 429,000 | $4,339,000 | |

#### Operation and Maintenance

| | | | |
|---|---|---|---|
| Generating and pumping plant installations 475,000 hp. at $0.75 per hp. | 356,000 | | |
| Rock-fill dams | 75,000 | | |
| Navigation structures | 20,000 | 451,000 | |
| Total | | | $4,790,000 |

### Transmission Line

#### Fixed Charges

| | | | |
|---|---|---|---|
| Interest on capital cost 6-1/2% on $19,173,000 | 1,246,000 | | |
| Depreciation 1.3% on $16,000,000 | 208,000 | | |
| Taxes on capital cost 1-1/2% on $19,173,000 | 288,000 | 1,742,000 | |
| Operation and Maintenance | | 150,000 | |
| Total | | | 1,892,000 |
| Grand Total | | | $6,682,000 |

19. It will be noted that insurance does not appear as a separate item in the above statements of annual charges. This item was not overlooked. It is included in "operation and maintenance". Workmen's compensation insurance is properly chargeable to operation, and insurance on machinery is chargeable to maintenance.

20. The applicant's estimate of annual charges on the main plant and Haycock Harbor plant, exclusive of interest on investment, is $781,500 as follows:

| | |
|---|---|
| Operation and maintenance (including labor, materials, repairs, management, and supervision | $406,000 |
| Depreciation (calculated to amortize part of the investment in machinery in 20 years at 4% interest | 330,000 |
| Insurance | 45,500 |
| Total | $781,500 |

21. The amount set up by the applicant to be amortized by the depreciation reserve, does not include contingencies, engineering, or interest during construction. These costs are parts of the capital cost and should be included. Without interest during construction, but including engineering and contingencies, the cost of the project included by the applicant, as subject to depreciation, amounts to $11,069,000.

22. The applicant apparently assumes an indefinite life and consequent zero depreciation for the balance of the project, which, without interest during construction (and exclusive of the long-distance transmission line), is estimated by the Commission's staff as $32,817,000. While with proper maintenance the earth and rock-fill structures might be assumed to endure for such lengths of time as to render a depreciation rate negligible, it is believed that since the concrete structures are subject to the destructive action of sea water, their useful life will probably not exceed 50 years. Therefore, the concrete structures have been considered along with other depreciable property.

23. In its consideration of the economics of the project, the applicant has made no provision for the payment of taxes. This office has no information to justify a conclusion that the applicant as a private corporation, would be immune from taxes. Certain expressions of opinion to the effect that the State and political subdivisions thereof might waive taxes, have been seen, but such statements are not regarded as conclusive. It is assumed, therefore, that the project, unless built by the United States, would have to bear its part of the tax burden.

24. The estimate of the amount of energy available from the project involves certain assumptions as to market load; that is, load factor and the shape of load curve. It should be borne in mind that the main tidal plant at Eastport would necessarily operate under great variations in head, output, and capacity, and that extensive use must be made of the storage plant at Haycock Harbor, both to regulate the energy output and to furnish additional capacity. In order to use the storage plant to the extent contemplated by the applicant, a large proportion of the power output of the main plant must be "stored" in the reservoir, with only a portion of it going direct to the consumer. Since this storage involves pumping with electric power, a considerable energy loss will occur in the storage operation. It is obvious that the total amount of energy available for sale will depend largely upon the amount which is sold directly from the main plant, this energy not being subject to storage losses; and this in turn depends on the load curves or consumers' requirements, and at present can only be assumed.

25. It is evident that the operating program of the various pumps and generators to meet the demands of a varying load, will be quite complicated if pumping is to be kept at a minimum. Computations of the output, based on a typical load curve at 40 percent load factor, have been made in this office, and the results obtained are in reasonably close agreement with the claims of the applicant. As a result of these studies, the conclusion has been reached that the applicant's estimates of output are sufficiently accurate for present purposes. It is assumed, therefore, that the plant output at the generators would be 487,000,000 kilowatt-hours per year, and that the prime capacity would be 139,000 kilowatts, sufficient to deliver the output at 40 percent load factor.

26. Using the applicant's output figures, and annual charges as estimated in this office, the unit cost of project power in mills per kilowatt-hour is estimated as follows:

| Market Area | 6-1/2 Interest | 4% Interest |
|---|---|---|
| Eastport area - 487,000,000 KWH | 9.8 | 7.1 |
| Boston area* - 438,000,000 KWH | 15.2 | 11.0 |

*Power transmitted to Tewksbury in vicinity of Boston to interconnect with other New England power systems.

27. Market for Power. The published reports of the United States Geological Survey show that the production of electric power for public use in the State of Maine increased from 352,000,000 kilowatt-hours in 1920 to 731,000,000 kilowatt-hours in 1930, or at the average rate of 38,000,000 kilowatt-hours per year. In the year 1930, 91 percent of the total production in Maine was by hydroelectric plants, and in 1932, 99

percent was generated by hydro plants. If the public-use-market growth of the entire State of Maine could be had for this project, 13 years of market growth, as indicated by the 1920-1930 rate, would be required to absorb its 487,000,000 kilowatt-hours annual production.

28. The applicant suggests that a large part of the power might be used in electrochemical and electrometallurgical industries, which might be attracted to the immediate vicinity of Eastport as a result of the construction of the project. Such suggestions are, of course, purely speculative. Moreover, the cost of power from this project appears too high to attract such industries. If it were known in advance that the output could be sold to electrochemical and electrometallurgical industries, operating at high load factor, the capital cost of the project could be reduced somewhat, since the installed capacity at the main plant and at the pumped storage plant would not need be so large. The reduction in cost would not be great, however, since the more expensive features would not be changed.

29. It is impossible to state the rate at which the power would have to be sold in order to attract heavy industries to that locality in sufficient numbers to consume the output of the project, but it may logically be assumed that if and whenever power cost is a major consideration, industries will seek locations where power is especially cheap. It should be borne in mind, however, that such industries consume power at relatively high load factor, whereas, the applicant has planned this project so that it will be most suitable for serving a general utilities or domestic market with load factor of about 40 percent. The project would have for sale a relatively valuable and expensive class of power characterized by low load factor and dependability, whereas heavy industries require cheap power and high load factors. The project, while it has 139,000 kilowatts of prime capacity at 40 percent load factor, representing about 487,000,000 kilowatt-hours annual output, could, because of the limiting capacities of the tidal basin, furnish only about the same energy output at a higher load factor. At 80 percent load factor, for example, the effective prime capacity would be only about 70,000 kilowatts, leaving the remaining installed capacity useless and ineffective.

30. If it be assumed that the project would be built by the United States, with money at 4 percent and no taxes, the estimated cost of the power in mills per kilowatt-hour would be as follows:

| Market Area | 4% Interest |
|---|---|
| Eastport area - 487,000,000 kwh | 5.63 mills |
| Boston area - 438,000,000 kwh | 8.78 mills |

31. Attention is invited to the following statement contained in the report of the PWA State Engineer on the application, a copy of which was transmitted to the Commission with Docket No. 1641.):

> "The State Engineer's office has carefully considered the highest price that power could be marketed by this project to large industries. Based on a load factor of 40%, it is the opinion of the State Engineer's office that 4½ mills per kilowatt hour would be the maximum price."

32. While the Commission's staff does not have special information as to exact rates paid for power by electrochemical and electrometallurgical industries, it is general knowledge that such rates are low. It should not be assumed, however, that such industries would use power on a 40% load factor. It is probable that the load factor would be in excess of 70 percent.

33. The applicant has suggested the possibility of finding a market for so-called 2,000-hour power (about 25 percent load factor) in the Boston area at a price of about 13 mills per kilowatt-hour. Based upon the applicant's estimate of prime capacity, it would be impossible to deliver to Tewksbury more than about 250,000,000 kilowatt-hours per year at 23 percent load factor. If money could be obtained at 4 percent, and if the project were immune from taxes, it is estimated that the unit cost of delivering 250,000,000 kilowatt-hours per year to Tewksbury would be 15.4 mills per kilowatt-hour.

34. Competitive sources of power supply. At least two other sources of power supply for the Eastport region are worthy of serious consideration as competitors of the "Quoddy" project; namely, steam electric power and water power from the rivers of Maine.

## Steam Electric Power

35. The cost of steam electric power from a tidewater plant at Eastport has been estimated, for comparison with "Quoddy" power, at load factors ranging from 40 percent to 80 percent. In this connection it should be observed that the output from the Quoddy plant would be substantially the same (about 487,000,000 kilowatt-hours) for various load factors ranging from 40 percent upward. Therefore, the unit cost of the hydro energy would remain about constant for the various load factors, since the annual charges would remain constant. On the contrary the unit cost of steam electric energy would decrease rapidly with an increase in load factor.

36. Steam electric equipment is not as dependable as hydroelectric equipment of the same capacity, and for this reason it is assumed that 15 percent reserve capacity must be provided in the steam plant, in order that its dependability might be equal that of the hydro plant. The "Quoddy" hydro plant would have dependable capacity of 139,000 kilowatts. The steam plant of equal effective capacity would have an installation of 160,000

kilowatts.

37. Coal has been purchased at Boston during the period 1926 to 1933, inclusive, for steam electric power production, at prices ranging from $4.83 per ton in 1926, to $3.96 per ton in 1933. (The word "ton" as used in this report means 2,000 pounds) The average price for the four high years, 1926 to 1930, was $4.56 per ton. It is assumed that coal can be obtained at Boston in the future for $4.60 per ton. The water freight from Hampton Roads to Boston is 63 cents per ton. It appears that the only difference in the cost of coal at Eastport and at Boston would be the difference in water freight in the two points. It is assumed that coal could be obtained at Eastport at a price of $5.00 per ton.

38. The coal used at Boston contains approximately 14,800 b.t.u. with mositure expelled, and 14,300 b.t.u. as fired. It is mined in the New River fields, transported to Norfolk by rail, and thence to Boston by water.

39. A modern efficient steam electric plant, such as would be constructed, would consume not more than 12,800 b.t.u. per kilowatt-hour when operating at high capacity factor. It is assumed that the coal consumption at 40 percent capacity factor would be one pound, or 14,300 b.t.u. per kilowatt-hour.

40. Fixed charges on steam electric capacity are taken at 12 percent per year on the capital cost, made up as follows: Interest 6½ percent, taxes 1½ per cent, and depreciation 4 percent. The capital cost of a plant of this large capacity would probably be somewhat less than $100 per kilowatt, but the cost is assumed at $100.

41. Operation and maintenance costs, other than fuel, are assumed as ranging from 0.8 mills per kilowatt-hour at 40 percent load factor to 0.6 mills per kilowatt-hour at 80 percent load factor.

42. On the basis of capital cost of $48,878,000 for the Quoddy plant and $16,000,000 for a steam plant having equal effective capacity, and assuming interest at 6½ percent and taxes at 1½ percent, the comparative cost of power at the various load factors, has been estimated as follows:

| | Effective Capacity | Mills per kilowatt-hour | | |
|---|---|---|---|---|
| | | 40% L.F. | 60% L.F. | 80% L.F. |
| Steam | 139,000* KW | 7.24 | 5.71 | 4.92 |
| Hydro | 139,000 KW | 9.84 | 9.84 | 9.84 |

* 15% reserve capacity installed, making total steam capacity of 160,000 kilowatts.

43. Assuming that money could be obtained at 4 percent, and that there would be no taxes, the comparative costs per kilowatt-hour at the various load factors have been estimated as follows:

| | Effective Capacity | Mills per Kilowatt-hour 40% L.F. | 60% L.F. | 80% L.F. |
|---|---|---|---|---|
| Steam | 139,000* KW | 5.93 | 4.82 | 4.16 |
| Hydro | 139,000 KW | 5.63 | 5.63 | 5.63 |

* 15% reserve capacity installed, making total steam capacity of 160,000 KW.

44. If the output from the Quoddy hydro plant should be transmitted to the Boston area, it is believed that the ordinary advantage which hydro capacity has over steam capacity, as to dependability, would be sacrificed. It is assured, therefore, that a tidewater steam plant at Boston, with capacity of 125,000 kilowatts, would be equally as effective for serving the Boston area, as the 125,000 kilowatts which could be delivered to Tewksbury from the Quoddy plant.

45. With money at $6\frac{1}{2}$ percent and taxes at $1\frac{1}{2}$ percent of capital costs, the following comparative kilowatt-hour costs of steam electric power at Boston and Quoddy hydro power at Tewksbury, have been computed:

| | Effective Capacity | Mills per Kilowatt-hour 40% L.F. | 60% L.F. | 80% L.F. |
|---|---|---|---|---|
| Steam power at Boston | 125,000 KW | 6.52 | 5.16 | 4.37 |
| Quoddy power at Tewksbury | 125,000 KW | 15.2 | 15.2 | 15.2 |

46. With money at 4 percent and no taxes, the following comparative kilowatt-hour costs of steam power at Boston and Quoddy hydro power at Tewksbury have been computed:

| | Effective Capacity | Mills per kilowatt-hour 40% L.F. | 60% L.F. | 80% L.F. |
|---|---|---|---|---|
| Steam power at Boston | 125,000 KW | 5.38 | 4.40 | 3.80 |
| Quoddy power at Tewksbury | 125,000 KW | 8.78 | 8.78 | 8.78 |

47. In the comparative costs given in paragraph 42, 43, 45 and 46 shown, it should be understood that the output from the two plants would be the same at 40 percent load factor only. The output from the Quoddy plant would remain about constant, at substantially 487,000,000 kilowatt-hours per year for load factors of 40 percent and greater, whereas the output from the steam plant would increase in direct proportion to the load factor.

## Power from Rivers in Maine

48. The War Department in a report dated December 4, 1930, and published as House Document No. 658, 71st Congress, 3rd Session, states that on the main stream of the Kennebec River there are 12 undeveloped power sites with a combined head of 618 feet, and aggregate power capacity of 97,000 horsepower available 90 percent of the time. The report estimates that these sites could be developed with a total installation of 194,000 horsepower at a cost of $29,000,000. The present storage on the Kennebec amounts to 932,000 acre-feet, and the report indicates that 220,000 acre-feet additional storage could be provided at low cost.

49. The War Department, in House Document No. 652, 71st Congress 3rd Session, reports that 7 of the most favorable undeveloped sites on the main stream of the Penobscot River, have aggregate power capacity of 42,700 horsepower available 90 percent of the time; and that these sites could be developed, with installation of 85,400 horsepower, at a cost of $13,700,000. The report states further that these plants would benefit from existing storage of 1,926,000 acre-feet, with the possibility of 300,000 acre-feet additional storage being provided at a cost of $450.000.

50. Investigations by the Commission's staff indicate that for the 11-year period, July 1920 to June 1931, the regulated prime power at the 12 most desirable sites on the Kennebec River would have been 85,000 kilowatts; and that for the 14-year period, September 1917 to September 1931, the regulated prime power at the 7 most desirable sites on the Penobscot River would have been 55,000 kilowatts. These two rivers could furnish annually from the sites mentioned, and as yet undeveloped, 1,226,000,000 kilowatt-hours of prime energy. Such a project would have an advantage over the Quoddy tidal project in that development could proceed in steps as required by market growth.

51. It was impossible in the brief time available for investigation of the Quoddy project, to make a thorough investigation of potential power available on Maine Rivers and prepare detailed estimates of the cost of such power. It seems probable, however, that power could be obtained more cheaply from the Maine rivers than from the tidal project.

## Comment

52. The applicant has submitted a statement purporting to show that taxes on the main plant and the Haycock Harbor plant would be only $339,000 per year. If correct, this would indicate that taxes in Maine are extremely low in comparison with other states. Presumably this figure is based upon the applicant's estimate of cost, or some part thereof, and the applicant's estimate is regarded as materially too low. It is believed, therefore, that the above figure would prove inadequate. If, however, it be assumed that taxes on the main plant and the Haycock Harbor plant would be $339,000 per year, and that taxes on the transmission line to Tewksbury would be correspondingly reduced, the kilowatt-hour costs shown in paragraph 26 would become as follows:

| | 6% Interest | 4% Interest |
|---|---|---|
| Eastport (switchboard cost) - 487,000,000 KWH | 9.0 | 6.3 |
| Tewksbury (Boston area) - 438,000,000 KWH | 14.1 | 9.9 |

and the kilowatt-hour costs shown in paragraph 45 would become as follows:

| | Effective Capacity | Mills per Kilowatt-hour 40% L.F. | 60% L.F. | 80% L.F. |
|---|---|---|---|---|
| Steam power at Boston | 125,000 KW | 6.3 | 5.0 | 4.3 |
| Quoddy power at Tewksbury | 125,000 KW | 14.1 | 14.1 | 14.1 |

53. On a project of this character, contingent costs could be very high. There is no basis of experience in such matters, since no comparable projects have ever been constructed. Although it would seem wise and prudent to make a liberal allowance for contingencies -- say 15 percent -- the estimates of cost, upon the basis of which annual charges have been figured include only the customary ten percent.

54. It is not desired to leave the impression the the consummation of the project might be impossible, since on the contrary it is believed that no insuperable difficulties would be encountered.

## Conclusions

55. No market exists in the vicinity of Eastport for Passamaquoddy power at this time, and there is no definite prospect of a local market being provided for this power.

56. The possibility of selling the power in the Boston metropolitan area is precluded by the prohibitive cost of delivering the power to that area. Even with money at 4 percent and no taxes, it would be impossible for this project to compete in the Boston area with steam electric power produced with money at commerdal rates of interest and subject to taxation.

57. Under very favorable assumptions, with money at 4 percent and no taxes, it is estimated that the switchboard cost of "Quoddy" power would be 5.65 mills per kilowatt-hour; and to afford a profit the selling price would, of course, be higher. This is not cheap power. But even though it might be lower than the prevailing price of industrial power in that section of Maine, heavy industries would not necessarily be attracted, since they must locate in proximity to still cheaper power.

58. With money at commercial rates of interest and taxes to pay, this project could not compete successfully with a tidewater steam electric plant at Eastport.

59. With money at 4 percent and no taxes, the switchboard cost of "Quoddy" power, at 40 percent load factor, would be slightly less than the corresponding cost of steam electric power. This is an apparent rather than real advantage, however, since the steam plant would be constructed in units of about 35,000 kilowatts as required, with initial outlay of less than $4,000,000 as compared with the enormous initial investment in the hydro project. Moreover, the steam electric power would be cheaper at the higher load factors.

60. The development of tidal power in Passamaquoddy Bay should not be seriously considered until after the potential water powers on the rivers of Maine have been thoroughly investigated. Such an investigation might disclose that power could be developed on these rivers and transmitted to Eastport at a cost below the switchboard cost of "Quoddy" tidal power.

61. It is my opinion that the Passamaquoddy Bay tidal project would be an unsuccessful venture, either with money at Commercial rates of interest or at 4 percent interest.

ROGER B. MCWHORTER

Chief Engineer

January 2, 1934.

APPENDIX "E"

To the Hon. Louis J. Brann,
Governor of Maine
Augusta, Maine

My dear Governor:

I desire to submit in behalf of the Passamaquoddy Bay Commission appointed by you in July last, their report which you will find in two parts:

First, the conclusions of your Commission, and

Secondly, a supporting report technical in detail prepared at our request by the Maine State Planning Board and its consulting engineers.

Since the organization of this Commission late in July we have diligently attempted to carry out the mandate which you laid upon us on our appointment; to report as promptly as possible on the desirability of the Quoddy project giving all due consideration to the social and economic aspects of the undertaking, but accepting as reasonably feasible the engineering conclusions already reached by Mr. Dexter Cooper and other distinguished engineers.

Throughout our study we have had valuable aid from the Secretary of the Interior and other officials of the Public Works Administration. We also desire to acknowledge with gratitude a grant from the Governor and Council of the State of Maine to aid in the technical investigation necessary. We desire to express our appreciation also for the very great assistance rendered us by the Maine State Planning Board in the preparation of the technical report on which we have placed great reliance.

Our unanimous conclusions are:

First, that the Quoddy project can only be constructed at this time as a Federal project; and

Second, as a Federal project it should be undertaken at once and carried to completion as promptly as efficiency in construction will permit.

In arriving at these conclusions that the whole Passamaquoddy project receive prompt and sympathetic consideration from the administration in Washington, we desire to state emphatically that it would properly come under a program of public works because it would undoubtedly employ for many months a large number of people now on relief rolls, and would in the future bring lasting benefit to the State of Maine. We would argue for Federal support for this project largely on the grounds of social desirability, that is, of benefit in the long run and in many ways without definite assurance that the project would be within a specified number of years self-liquidating.

In the first place, it seems to us clear that this project must be undertaken, if at all, by the Federal government and financed by Federal funds under Federal control. In the present economic situation private capital would not be available and the government has already denied a loan to a private corporation on the ground that a sufficiently sure market for the power generated has not been shown. The State of Maine is prevented on constitutional grounds from borrowing a sum of money sufficiently large to finance such an undertaking and therefore would be unable, even if willing, to assume control. If therefore Quoddy Dam is to be built it must be built by the Federal government and financed at a low rate of interest on the ground of public interest and social desirability rather than with the assurance of definite amortization of money advanced, although undoubtedly in time there should be a reasonable return.

There are of course many legal problems involved, but your Commission believes that such problems lie outside the function of this Commission which ought to deal with broad underlying principles. Furthermore, such legal questions can only be properly answered in the different departments at Washington.

After having examined the reports of government engineers we can take for granted the engineering feasibility of the project; that has never indeed been seriously questioned. Nor is it our function to go in detail into the cost of production per kilowatt hour; that would depend a good deal on the interest charges, which are problematical. It is our opinion that Quoddy power would prove to be an important factor if properly developed in the whole problem of power in New England.

The question of market for power is naturally of very great importance; that question is discussed with much detail in the technical report of the engineers submitted with this statement. It would, however, require a prophet of the first order to predict the possible use of power a few years hence. To give two illustrations: A short while ago it was considered possible that all our railroads would soon be electrified. The development of the Diesel engine, however, has made some change in the situation. It is therefore impossible to predict how much power from Quoddy would be used by the railroads in the near future. That question is still a very open one. Improvements and inventions are constantly being made in the transmission lines and it would not be surprising if within a few years it would be possible to transmit power for more than two hundred and fifty miles at economical rates. These and similar problems indicate how difficult it is to be dogmatic on any statement concerning the future market for power in the Quoddy region. If we judge the future by the past and recall how markets have often come to power sites, such, for example, as Niagara, it seems clear that industry will still seek cheap power, and it is quite within the bounds of reasonable possibility that the manufacturing of stainless steel, aluminum, fertilizer, and other similar industries, might well be developed in the Quoddy region which is through climate and proximity to Europe particularly well adapted to such enterprises.

Your Commission, however, desires to base its main contention on the fact that the Quoddy project would be of great benefit to the people of the State of Maine. Maine people have always been independent, hard-working, frugal, self-reliant; their philosophy is based on the idea that every man should produce the wealth of which he was capable by industry and ingenuity; that he should live frugally and keep out of debt; that he should be self-supporting and independent. That attitude still prevails; but the people of Maine realize that conditions in the economic world have greatly changed and that Maine alone cannot prosper cut off from the central energizing power of the government. Maine has always been in an eddy of the national stream little affected by the tides of adversity and prosperity until the past few years. Since 1929 Maine has been watching other parts of the country receive very large sums from the federal government for flood control, irrigation control, power projects, and other purposes in the West and South. Today, perhaps with typical Yankee shrewdness, Maine feels that it is about time that she receive a modest portion of the vast sums that seem to be available, to be expended within her borders on a project that the majority of the people of the state believe will give great renewal to the industrial and agricultural life of Maine and will rehabilitate one of the most hard hit regions of the whole country.

It has been stated that "That situation which confronts Maine has some likeness to that which faced those states in the far west when the mines, which were the basis of their economic life, neared exhaustion". Those western states would have had a very hard time indeed had not an irrigated agriculture been substituted for the closed mines. Maine has of late years suffered the loss of some of her most important earlier industries, shipbuilding, ice, lumber, with pulp and newsprint severely injured, to mention but a few. It seems to be the part of wisdom to provide some kind of a substitute for those losses so that industrial life may be stirred anew, and the power project as Quoddy should furnish such an agency.

Agriculturally, Maine is not self-supporting; she has to buy agricultural products from the West and South. Unless her industrial activity can be increased she will have difficulty in meeting the drain on her purchasing power. If the eastern part of the state could be, in a liberal way, industrialized it would stir the life of the whole state and send a now rather sluggish blood of commerce coursing more rapidly through the veins of trade. But Maine not only needs such an industrial development in the eastern part of the state, there are many factors that are particularly helpful to such development. There is, for example, the climate. When people think of the old saying--Winter in Maine is not a season, it is an occupation--they forget that our climate is admirable adapted to factory life. It is cool during the summer thereby saving the heavy toll on the human frame by reason of the heat of machinery. Along the coast the temperature in winter is not severe. In January, for example, the average temperature at several points on the Maine coast is higher than at Des Moines, Iowa or Lincoln, Nebraska. This is another argument for the desirability of Quoddy.

Moreover, there is no question but that the building of the Quoddy Dam would be a great benefit to the state in connection with its unemployment problem. Already the federal government has expended hundreds of thousands of dollars in Maine for the benefit of the unemployed and the needy. Many communities, both urban and rural, are struggling with the burdens caused by relief. The

Passamaquoddy project would undoubtedly absorb a large number of those who are now unemployed, would help to relieve the various Maine communities of excessive burden, and would restore the independence and self-respect of many Maine citizens who are now forced to accept government help, often without being able to do a good job in return for money received. It is perhaps going too far to say that the Quoddy project would solve the problem of relief in Maine, but it would undoubtedly be of the greatest possible practical help at the present time.

In conclusion, we may well call attention to the fact that although no man can predict with accuracy the uses to which power will be put, we are beyond question on the threshold of an age when electrical energy will be employed for many more purposes and in many more ways than those for which it is now used. Electrical energy coming from the tides of the Bay of Fundy will last longer than coal and oil and has the great advantage of being accurately predictable as to amount, unaffected by drought or flood.

Then too such a project appeals to the imagination. It has never been tried on such a large scale before. It is in the same category as the early transcontinental railways across the Rockies, or the early reclamation done in our arid regions, or the Panama Canal. It therefore would be of great interest to both engineers and laymen; persons from all parts of the country would undoubtedly visit the region to observe this latest indication of man's use of nature, the generation of power from the rise and fall of the tide.

Maine requests careful and sympathetic attention to this project primarily because it believes the state will be benefitted both now and in the future. It asks that the same principles be applied to its request that were used in planning and executing the great dams built in the South and West. It believes that no opportunity for a governmental undertaking of comparable magnitude can be found north of Alabama or east of the Alleghany Mountains.

In submitting this report the Commission is urgent in its findings that the national administration give prompt attention to this project and place it among the undertakings to be soon consummated from federal funds.

Having studied the whole question as requested and having submitted this report with the technical data prepared by the State Planning Board, the Commission believes that its work is now completed.

The members of the Commission joining in this report are William N. Campbell, of Sanford; Wingate F. Cram, of Bangor; Harry B. Crawford, of Houlton; E. S. French, of Portland; and Kenneth C. M. Sills, of Brunswick.

Very respectfully,

/s/ Kenneth C. M. Sills
Chairman

Brunswick, Maine
January 4, 1935

APPENDIX "F"

FEDERAL EMERGENCY ADMINISTRATION OF
PUBLIC WORKS.

WASHINGTON, D. C.

Department of Commerce
Bureau of Fisheries
Washington, D. C.

Mr. Dexter P. Cooper
Eastport, Maine

Dear Mr. Cooper:

At the meeting of the North American Fisheries Investigation Committee, a resolution was passed dealing with your new proposed power development in the vicinity of Eastport, the substance of which is as follows:

> Dealing with the proposed construction of power dams in the Passamaquoddy Bay area by the Dexter P. Cooper Company the Committee expressed the view that it need take no action on the company's new plan since it includes Cobscook Bay alone and there is no reason to expect that it would cause any serious and widespread damage to the fisheries. Inasmuch, however, as it is the expressed intention of the company to continue with its original project the committee endorsed the recommendation of one of its special sub-committees that Canada and the United States should carry on thorough investigations to determine the probable effects upon the fisheries of this earlier and larger plan as to Passamaquoddy Bay.

This information is being conveyed to the State Department and also to the Federal Power Commission. In the meantime, I am asking the State fisheries authorities to examine your plans and inform us if they desire any provisions for fishways in any of the dams.

I thought you would like to have this information at the earliest possible date.

Very sincerely,

HENRY O'MALLERY

Commissioner.

APPENDIX "G"

May 7, 1934.

Colonel Henry M. Waite, Deputy Administrator
Federal Emergency Administration of Public Works
Interior Department Building,
Washington, D. C.

Dear Colonel Waite:

I understand that the Public Works Administration has under consideration at least two projects which involve the manufacture of aluminum or some other form of light weight metal, and that it is urged in support of these projects that they would reduce prevailing prices. Of course I am not competent to express an opinion upon the practicability or merits in other respects of any ofhthese projects. However, I do feel strongly that it would be of great benefit to the railroads if prevailing prices of light weight metals could be reduced. Looking into the future, I think I can see constantly increasing railroad use for such light weight metals, provided such development is not prevented by high prices. I believe that the use of light weight metals will prove to be of great advantage, not only in the field of passenger equipment but also in the field of freight equipment, and if I am correct in this belief, anything that can be done to lower the cost of such metals and the prevailing price level will be most decidedly in the general public interest.

Very sincerely yours,

/s/ Joseph B. Eastman

E-B